Bird migration monitoring in the Saint Nikola Wind Farm territory, Kaliakra region in autumn 2014, and an analysis of potential impact after five years of operation

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Contents

SUMMARY

1. This report presents the results of 90 consecutive days of monitoring and mitigation at Saint Nikola Wind Farm (SNWF) in 2014, its 5th operational year. The continued purpose is to investigate the possible impacts on migrating birds.
2. Spatial and temporal dynamics in the numbers of different species passing through the wind farm territory during autumn migration 2014 (15 August to 31 October) are presented. The data from the autumn monitoring in the years 2008 to 2014 are used to investigate the potential change in species composition, numbers, altitude or the flight direction of birds observed in these seven years at SNWF.
3. The variations in numbers of species, absolute number of birds, overall altitudes of flight and migratory direction of birds most sensitive to wind turbines do not indicate an adverse effect of the wind farm on diurnal migrating birds.
4. The Turbine Shutdown System probably contributed to a reduced risk of collision during all years of operation within infrequent periods of intensive soaring bird migration and provided a safety mechanism to reduce collision risk for single birds and flocks of endangered bird species.
5. Results of trials in autumn 2014 for the efficiency of observers searching for collision victims and for carcass persistence rates were broadly similar to those in previous autumns (2009 and 2010) and continued to support the assumption that with a seven day inter-search interval under turbines approximately 50 % of collision victims of target species should be found.
6. 11 victims of collision were found, including two bird species of conservation significance, during 777 searches under all 52 turbines for casualties at an interval 7 days or less. Additionally one old skeleton of a pelican as well as an injured white stork rescued by the field ornithologists are reported, but cannot be associated with collision from turbine blades.
7. The predicted mortality rates by species based on preconstruction data on numbers of migrating birds are not supported by the mortality observed during any of the 5 years of operation of SNWF. The levels of mortality predicted pre-construction have not been recorded during operation. This is largely because ‘worst case’ predictions were based on BSPB data that substantially exaggerate

the numbers of migrants passing through SNWF. The results to date indicate that mortality at SNWF does not constitute a significant obstacle or threat, either physically or demographically to any of the populations of diurnal autumn migrants observed in this study.

INTRODUCTION

AES Geo Energy OOD constructed a 156 MW wind farm consisting of 52 turbines: the St Nikola Wind Farm (SNWF). In autumn 2008, SNWF did not exist; in autumn 2009 the facility was built but not operational (i.e. turbine blades were stationary), and in the autumns of 2010 - 2014 SNWF was operational. Systematic field studies have investigated the spatial and temporal distribution of migratory and breeding birds within this area in recent years; largely connected with the SNWF development.

The main results of the autumn monitoring of bird migration in the vicinity of SNWF in previous years are published at: http://www.aesgeoenergy.com/site/Studies.html. In these studies negligible collision mortality of migrating birds was found; indicating a high micro avoidance rate of the turbines by migrating bird species.

Studies at SNWF demonstrate that strong fluctuations in numbers of different species were correlated significantly with wind direction so that periodic and infrequent westerly winds coincided with peaks in soaring bird migration activity. Bird counts listed in previous SNWF reports on day to day monitoring by up to 6 observers clearly and repeatedly indicated that the wind farm is not situated on the main fly way of soaring bird species within Bulgaria. The main migration ‘highway’ obviously lies to the west of SNWF and stretches out 80 to 300 km from the coast (illustrated in Fig. 1).

This conclusion of studies at SNWF, published on the aesgeoenergy.com website have been affirmed independently by Michev et al. (2012) and in bird sensitivity maps – based on NGO data- for soaring birds migrating over Bulgaria http://natura2000.moew.government.bg/PublicDownloads/Auto/OtherDoc/276299/276299_Birds_120.pdf) On pages 151-171 of this document, for key species SNWF is shown to underlie a very small proportion of the migratory traffic.

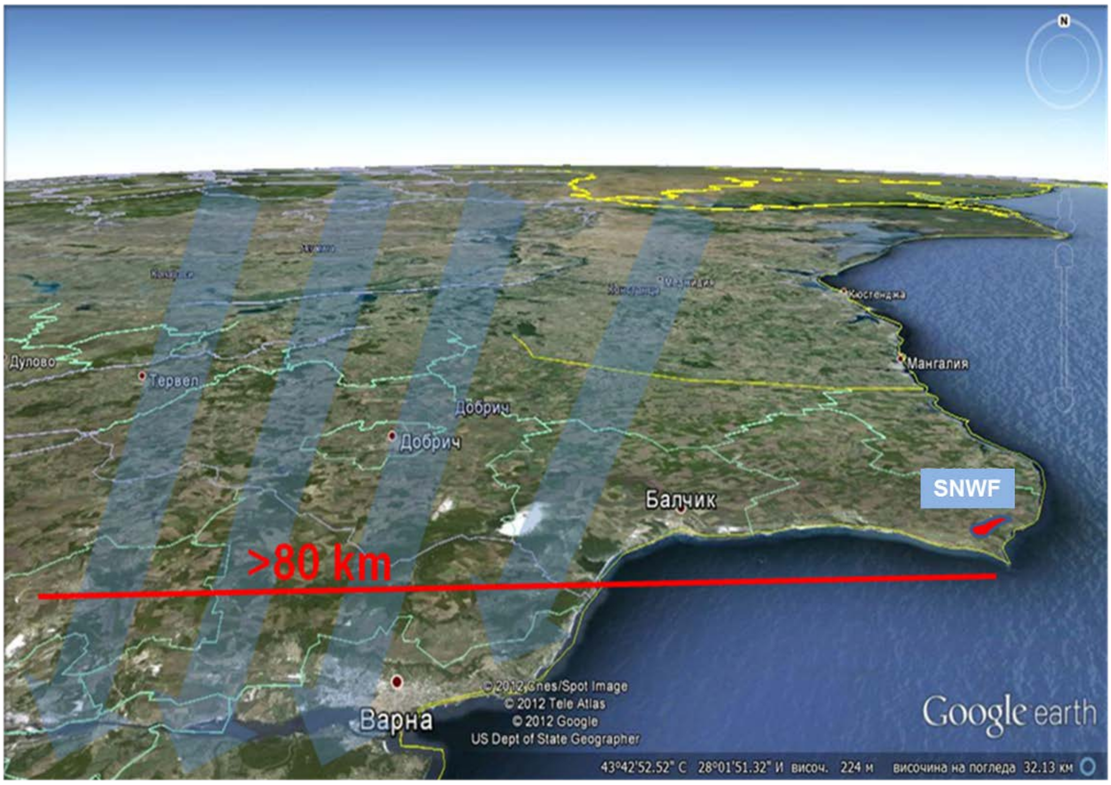

Figure 1. Schematic representation of the main autumnal migratory flyway (blue arrows), and the location of SNWF in red.

The Saint Nikola Wind Farm (SNWF) is located in NE Bulgaria, inland of the Black Sea coast near the village Bulgarevo and Kavarna. The territory of the site consists mainly of arable land with different crops (wheat, sunflower, rapeseed, flax), intercepted with roads and shelter belts. The territory of SNWF does not provide any water bodies or wetlands which can be associated with habitats or roosting sites of migrating soaring birds known as reasons for aggregation of notable numbers of birds during migration.

In previous SNWF autumn reports the major focus was assessment of potential barrier effect on birds migrating through the territory and the level of collision mortality of migrants. The analysis of the data until now showed no evidence for cumulative long term changes in the migratory bird fauna.

The present report updates the information on spatial distribution and temporal presence of birds in SNWF during autumn 2014 with, as in previous reports, special focus on soaring species deemed most sensitive to wind turbines.

METHODS

The study area

SNWF is located in NE Bulgaria, approximately three to seven kilometers inland of the Black Sea coast and the cape of Kaliakra. The wind farm lies between the road from the village of Bulgarevo to St. Nikola (municipality of Kavarna), and the 1st class road E 87 Kavarna – Shabla.

Study duration and equipment

The study was carried out in the period 15 August – 31 October 2014 by up to six field ornithologists. The surveys were made during the day, in a standard interval of time between 8 AM and 6 PM astronomic time. In the autumns 2008 – 2012 the study period was shorter covering a total of 45 days (15 August – 30 September); the period of the most intensive migration. The increase of the observation period in 2013 and 2014 aimed, to attain an even higher assurance level in the mitigation of collision risk with respect to all potentially sensitive bird species that may appear in SNWF until the end of October. In October, due to the much reduced migration intensity, the number of field ornithologists was reduced from six to three.

The radar has been operational throughout the migration period. The scanning program in 2014 was the same as in previous years and is not repeated in this report. The program is detailed in the Owner Monitoring Plan and previous autumn reports, all published on the AES website.

Basic Visual Observation Protocol

The autumn 2014 study involved direct visual survey of all passing birds from several observation points (Figure 2). Field observations followed the census techniques according to Bibby et al. (1992). Point counts were performed by scanning the sky in all directions. Height estimates and distances to the birds were verified with land mark constructions around the observation points previously measured and calibrated by GPS. The surveys were carried out by means of optics, every surveyor having a pair of

10x binoculars and all observation points were equipped with 20 – 60x telescope, compass, GPS, and digital camera.

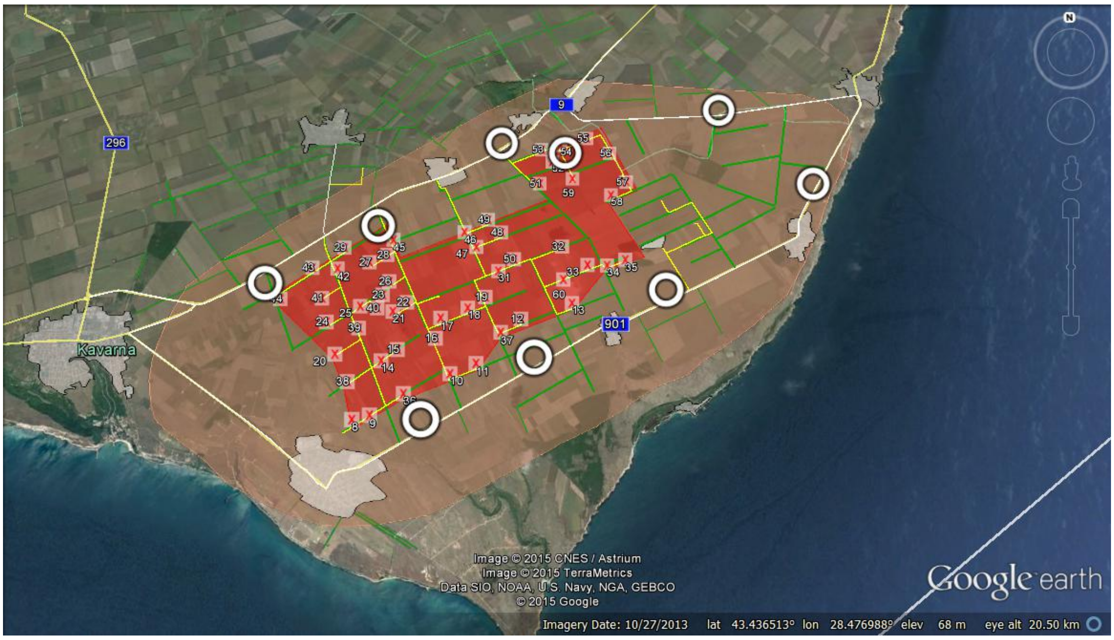

Figure 2. Map of the "SNWF" study area (red plot), and the "core study area" (brown area) covered by the autumn monitoring 2014 observations and location of the observation points.

The basic temporal survey protocol was not changed in the period 2008 – 2014 (other than the temporal extension in 2013 and 2014) in order to allow comparable data between years. As noted in previous reports, 2009 was exceptional in the spatial survey protocol because the observation points were moved northward to test the early warning system (TSS) for approaching flocks of birds. The northerly shift in the observation points in 2009 means that many data of migratory metrics (notably, flight direction) were likely not comparable with the years before or since. In 2009, SNWF had been constructed but was not operational.

The observation effort was sufficient for coping with the volume of avian migratory traffic, and no observer was ‘swamped’ in time under the circumstances outlined by Madders and Whitfield (2006). All details about the specific visual observation protocol are presented in a number of previous autumn reports and in the Owner Monitoring Plan (OMP) and will not be repeated here: http://www.aesgeoenergy.com/site/images/21.pdf (studies page).

All observers were qualified specialists in carrying out the surveys of bird migration for many years including previous autumn surveys at SNWF. Some of the observers are active members of the BSPB (BirdLife Bulgaria).

List of participants in the autumn observations, 2014

Dr Pavel Zehtindjiev
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Institute of Biodiversity and Ecosystem Research
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Victor Metodiev Vasilev
Field ornithologist
Senior researcher in the Faculty of Biology
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Karina Ivailova Ivanova

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Method of Collision Victim Monitoring

The collision monitoring methodology followed that developed in the USA for bird collision monitoring at wind farms (Morrison 1998). The detailed description of the protocol is given in par. 1.6 and 2.4 of the Owners Monitoring Plan (OMP http://www.aesgeoenergy.com/site/Studies.html.). Actual carcass numbers found during the systematic searches typically fail to find all dead birds. Two principal factors, being searcher efficiency (searchers fail to find all dead birds) and removal/disappearance of dead birds before the searcher can potentially find them. Accounting for these two potential biases can substantially improve estimates of collision mortality at operational wind farms derived from searches around turbine bases. In 2014 trials were undertaken in order to provide for such correction. These trials are compared with similar ones undertaken in 2009 and 2010.

Statistical methods

The number of observed species, individuals as well as their average altitude of flight (by species and years) is presented in a number of tables for direct comparison across the autumn seasons of 2008 - 2014.

The altitude of migration in different autumn seasons was evaluated for significance by its mean value, standard error and standard deviation in data analysis software system STATISTICA (StatSoft, Inc. (2004, version 7. http://www.statsoft.com/). The mean flight direction as well as its significance level, for every species and group of species was calculated according to standard circular statistics (Batschelet 1981). Circular statistics was performed with Oriana (Oriana - Copyright © 1994-2009 Kovach Computing Services). This program compares two or more sets of circular distributions (directions) to determine if they differ. The tests were performed pairwise, so that each pair of samples was compared separately.

Many of the basic statistical parameters of circular distributions (directions) are based on the concept of the mean vector. A group of observations (or individual vectors) have a mean vector that can be calculated by combining each of the individual vectors (the calculations are explained in most books about circular statistics). The mean vector has two properties; its direction (the mean angle, **μ**) and its length (often referred to as **r**). The length ranges from 0 to 1; a higher r value indicates that the observations are clustered more closely around the mean than a lower one. Details about the Oriana software are available at: http://www.kovcomp.com/

Turbine Shutdown System (TSS)

The principles to selectively stop turbines or the entire wind park to reduce risk of collisions are described in par. 1.5 of the Owners Monitoring Plan (OMP).

The TSS protocol was followed in order to reduce collision risk during the extended period of study in autumn 2014, between 15 August and 31 October. Turbine shutdowns are ordered by the Senior Field Ornithologist or -when delegated to- field ornithologists in case of any perceived risk, such risk as per the discretion of the ornithologist.

RESULTS

Composition of species and number of birds passing through SNWF

As noted in the Methods, in 2014 the period of observation was extended to beyond the period of most intensive migration, August and September. In order to provide comparability between 2014 and previous years, however, to avoid bias associated with the extended observation period in 2014, the data presented below are based on a comparable time period (15 August to 30 September) unless otherwise stated.

The occurrence of species across all years is presented in Table 1. A total of 122 bird species have been observed in the wind farm territory during the consecutive autumn seasons of 2008 to 2014. The number of observed species varied from 48 to 80 in different years. Most species (80) were observed in 2014, in the 6th autumn after construction. There is no apparent difference in the number of species observed in 2008 (before the construction of the wind farm) and during the later period when the wind farm was present (2009 – 2014).

Table1. List of species observed in the SNWF during period 15th August – 30th September in pre-construction (2008) and post-construction (2009, 2010, 2011, 2012, 2013 and 2014 in grey) periods of SNWF. Hatched cells represent the years when the species was registered in SNWF.

N	Species	2008	2009	2010	2011	2012	2013	2014
1	*A. apus*	■	■	■	■	■	■	■
2	*A. arvensis*		■			■	■	■
3	*A. brevipes*	■	■	■	■	■	■	■
4	*A. campestris*		■			■	■	
5	*A. cervinus*					■	■	
6	*A. chrysaetos*			■	■	■	■	■
7	*A. cinerea*	■	■	■	■	■	■	■
8	*A. gentilis*	■	■	■	■	■	■	■
9	*A. heliaca*	■						
10	*A. melba*	■	■	■	■	■	■	■
11	*A. nisus*	■	■	■	■	■	■	■
12	*A. pennata*			■	■	■	■	■
13	*A. pomarina*	■	■	■	■	■	■	■
14	*A. pratensis*					■	■	
15	*A. purpurea*	■	■	■	■	■	■	
16	*A. trivialis*	■			■			
17	*B. buteo*	■	■	■	■	■	■	■
18	*B. oedicnemus*		■		■			

N	Species	2008	2009	2010	2011	2012	2013	2014
19	*B. rufinus*							
20	*B. vulpinus*							
21	*C. aeruginosus*							
22	*C. cannabina*							
23	*C. canorus*							
24	*C. carduelis*							
25	*C. chloris*							
26	*C. ciconia*							
27	*C. coccothraustes*							
28	*C. corax*							
29	*C. cornix*							
30	*C. coturnix*							
31	*C. cyaneus*							
32	*C. frugilegus*							
33	*C. gallicus*							
34	*C. garrulus*							
35	*C. livia domestica*							
36	*C. macrourus*							
37	*C. monedula*							
38	*C. nigra*							
39	*C. olor*							
40	*C. palumbus*							
41	*C. oenans*							
42	*C. pygargus*							
43	*D. major*							
44	*D.syriacus*							
45	*D. urbica*							
46	*E. alba*							
47	*E. calandra*							
48	*E. garzetta*							
49	*E. hortulana*							
50	*E. melanocephala*							
51	*F. cherrug*							
52	*F. coelebs*							
53	*F. eleonorae*							
54	*F. naumanni*							
55	*F. parva*							
56	*F. peregrinus*							
57	*F. subbuteo*							
58	*F. tinnunculus*							
59	*F. vespertinus*							
60	*G. fulvus*							
61	*G. glandarius*							
62	*G. grus*							

N	Species	2008	2009	2010	2011	2012	2013	2014
63	*G. cristata*							
64	*H. daurica*							
65	*H. icterina*							
66	*H. pallida*							
67	*H. rustica*							
68	*J. torquila*							
69	*L. cachinnans*							
70	*L. collurio*							
71	*L. megarhynchos*							
72	*L. melanocephalus*							
73	*L. minor*							
74	*L. ridibundus*							
75	*M. alba*							
76	*M. apiaster*							
77	*M. calandra*							
78	*M. cinerea*							
79	*M. flava*							
80	*M. migrans*							
81	*M. milvus*							
82	*M. striata*							
83	*N. percnopterus*							
84	*O. hispanica*							
85	*O. isabellina*							
86	*O. oenanthe*							
87	*O. oriolus*							
88	*O. pleschanka*							
89	*P. apivorus*							
90	*P. caeruleus*							
91	*P. crispus*							
92	*P. haliaetus*							
93	*P. leucorodia*							
94	*P. major*							
95	*P. montanus*							
96	*P. onocrotalus*							
97	*P. perdix*							
98	*P. pica*							
99	*P. viridis*							
100	*Ph. carbo*							
101	*Ph. collybita*							
102	*Ph. trochilus*							
103	*Pl. falcinellus*							
104	*R. riparia*							
105	*S. borin*							
106	*S. communis*							

N	Species	2008	2009	2010	2011	2012	2013	2014
107	*S. curruca*							
108	*S. rubetra*							
109	*S. vulgaris*							
110	*St. hirundo*							
111	*Str. decaocto*							
112	*Str. turtur*							
113	*T. nebularia*							
114	*T. glareola*							
115	*T. tadorna*							
116	*T. ochropus*							
117	*T. merula*							
118	*T.viscivorus*							
119	*U. epops*							
120	*V. vanellus*							
121	*Ph. ochrurus*							
122	*Ph. phoenicurus*							
	Number of species	76	79	48	71	79	77	80

Examples of rare soaring species observed sporadically in some autumns are Common Crane, Griffon Vulture, Egyptian Vulture, Imperial Eagle, Golden Eagle, Red Kite, Saker Falcon, Lesser Kestrel and Eleonora's Falcon.

36 species were observed every autumn season in the period 2008 – 2014. Regular migrants through the territory included White Pelican, White Stork, Levant Sparrowhawk, Common Buzzard, Honey Buzzard and the Lesser Spotted Eagle. Imperial Eagle, Dalmatian Pelican, and Lesser Kestrel are rare in general and these sporadic observations are probably unrelated to SNWF pre-construction and post-construction periods. By contrast, another 27 species of birds were not recorded in 2008, but observed in the longer (six years, to date) post-construction period. Among such species were, for example, many birds of prey like Golden Eagle, Saker Falcon, Black Kite; waders like Northern Lapwing, Green Sandpiper, Common Greenshank, Eurasian Stone-curlew; herons like Purple Heron, Great Egret, Little Egret; and many small passerine bird species. The occurrence of these species after construction should probably not be attributed to any beneficial effect of SNWF's presence, but (again) to vagrancy.

Three new species in the SNWF territory were observed in autumn 2014: wood sandpiper (*Tringa glareola*), blackbird (*Turdus merula*) and mistle thrush (*Turdus* *viscivorus*). It is important to note that all of them were observed in the period comparable with the previous studies, 15th August- 30th September. The probable reason why these species were not observed in previous years at SNWF is the relatively low number of breeding areas and suitable habitats respectively for these species in the vicinity of the study area. The three species are common species elsewhere in Bulgaria.

Two vulture species were registered only after the construction of SNWF. In the available literature concerning the region including Standard Data Forms of the nearby NATURA 2000 zones, the two species are not listed. The Griffon vulture was observed in autumn 2010 and 2012, 2013 and 2014. In 2014 one Griffon Vulture was observed on September 13 at 900 m height crossing SNWF territory. The Egyptian Vulture was not observed in SNWF in 2014.

Absolute counts of soaring species which were most numerous, together with some additional species with high conservation value, are presented in Table 2.

Table 2. Numbers of birds recorded as passing through the territory of SNWF (primarily soaring water birds and birds of prey) in seven autumn seasons of pre-construction (2008) and post-construction (2009 – 2014) periods.

Species	2008	2009	2010	2011	2012	2013	2014
A. brevipes	95	210	976	290	94	650	138
A. chrysaetos			2	2	1	1	2
A. cinerea	120	259	26	40	56	70	113
A. gentilis	10	6	5	11	22	38	9
A. heliaca	2						
A. nisus	44	44	70	73	44	206	101
A. pennata			5	1	9	13	7
A. pomarina	44	9	80	76	31	1966	509
A. purpurea		59	11	1	7	3	
B. buteo	146	390	180	459	238	2345	1073
B. oedicnemus		1		1			
B. rufinus	163	151	34	30	33	28	41
C. aeruginosus	327	268	341	271	179	473	298
C. ciconia	2998	87	24980	620	2525	11230	4639
C. cyaneus	5	1		1		3	18
C. gallicus	29	19	18	25	60	88	26
C. macrourus	8	27	18	4	7	7	15
C. nigra	8	8	8	1	13	488	48
C. olor		1	3				2

Species	2008	2009	2010	2011	2012	2013	2014
C. palumbus	10		1				26
C. pygargus	32	17	111	151	55	82	102
E. alba			1	1	5		
E. garzetta		7				11	1
F. cherrug		7		2	1		1
F. eleonorae	7			1	1		7
F. naumanni	1						
F. peregrinus		2	4	1		5	5
F. subbuteo	48	125	120	96	66	88	89
F. tinnunculus	138	357	45	120	67	103	89
F. vespertinus	11	180	1773	63	793	167	426
G. fulvus			1		1	2	1
H. pennatus	4	3	17	4	1	9	7
M. migrans	18	6	32	17	21	34	32
M. milvus			1	1		2	1
N.percnopterus					1		
P. apivorus	58	76	1549	152	115	4284	113
P. crispus	4						5
P. haliaetus	15	13	14	12	7	13	5
P. leucorodia	117	83	56	48		59	
P. onocrotalus	120	1190	252	277	1700	3285	1679
Ph. carbo	267	354	494	75	131		866
Ph.pygmaeus		19					
Pl. falcinellus	5	738					
St. hirundo		71					
T. tadorna		94			3		
Tr. ochropus		8			1		
Tr. glareola							3
T. merula							80
T. viscivorus							17
V. vanellus			1			7	
Total	4855	4890	31229	2927	6585	25760	10594
Number of species	30	35	33	33	30	31	36

Obviously the number of species as well as the absolute number of birds crossing the wind farm territory did not decrease after the construction of turbines. The most numerous species of soaring migrants; White Pelican, White Stork, Levant Sparrowhawk, Common Buzzard, Honey Buzzard and Lesser Spotted Eagle dominate the autumn migration across all years monitored. The absolute number of these species per year widely varied (Figure 3). Only when –non prevailing- strong westerly winds coincided with the passage of soaring birds at the latitude of the wind farm, were migrating birds apparently carried towards the coast and hence higher number of birds were observed in the wind farm area. The numbers of all soaring bird species varied by years with no decreasing trend for after the wind farm was constructed and started its operation (Figures 3 and 4). For example, the years with the greatest autumn migration of soaring birds over the wind farm territory were 2010, 2013 and 2014 i.e. years after construction of the turbines. In all the autumns the most numerous migrants are White Storks; also notable numbers of Honey Buzzards, White Pelicans, Common Buzzards, Lesser Spotted Eagles, Levant Sparrowhawks, Sparrowhawks and Black Storks regularly pass through or over the wind farm in all the years covered by our monitoring during autumn seasons (Table 2).

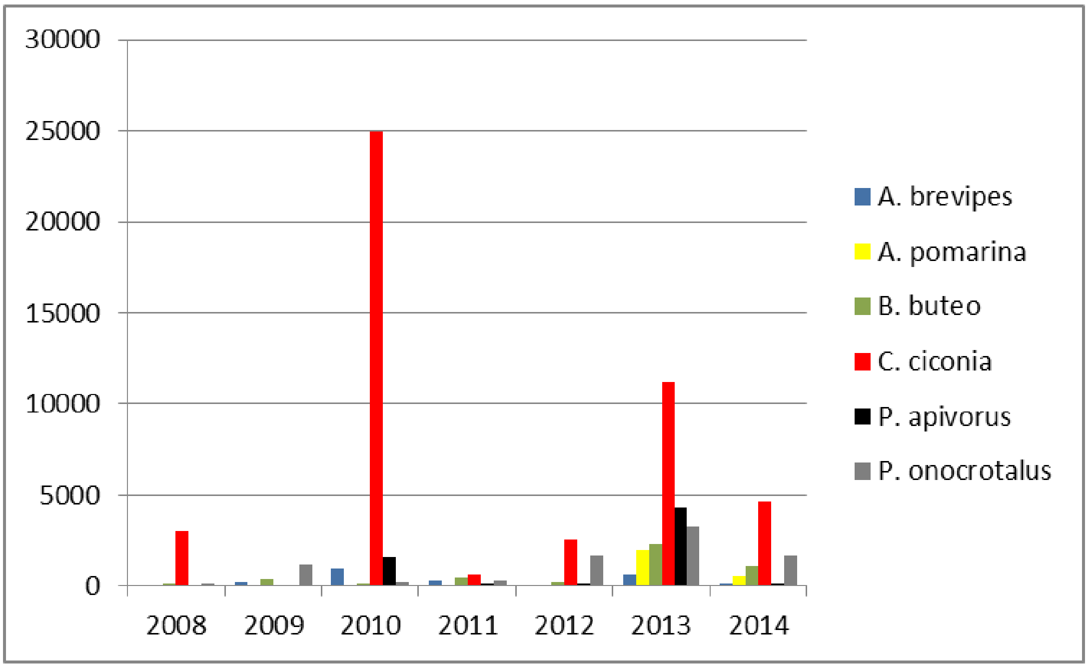


Figure 3. Variations in the total number of the most numerous soaring birds observed during autumn migrations in seven years (pre-construction and post-construction periods) in SNWF.

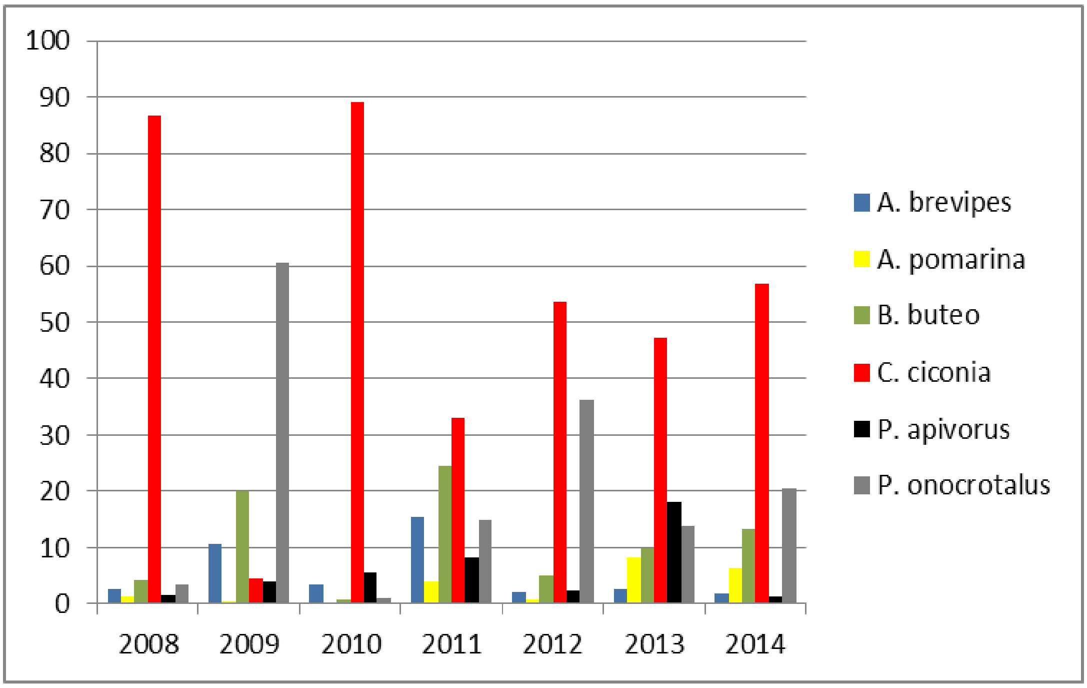


Figure 4. Proportional annual contribution of individual species (of the six most numerous soaring bird species recorded) to the total migratory traffic in and over SNWF in autumns 2008 – 2014.

As described in previous reports bee-eaters, swifts and swallows are other species that have occurred in relatively high numbers during seven years of SNWF monitoring. The recording of these species highly depends on the distance from the observer (in both vertical and horizontal visual planes) because of the small size of the birds (for details see autumn report 2013). Therefore visual observations on these species are limited to a few hundred meters and cannot be considered as absolute numbers for a given area and at all altitudes.

Bearing in mind that not all of bee-eaters, swifts and swallows crossing SNWF were detected, the results on the numbers of bee-eaters and hirundines (swallows and swifts) (hirundines not identified to the species level are not presented) registered in the period 2008 – 2014 are given in Table 3 below.

Table 3. The number of bee-eaters, swifts and swallows in SNWF in seven autumn seasons as observed in the period 15 August – 30 September.

Species	2008	2009	2010	2011	2012	2013	2014
A. apus	79	10	6	8	17	12	52
A. melba	515	16	536	234	47	127	58
D. urbica	1007	697		180	3	170	109
H. daurica	2	8		4	1		
H. rustica	2979	4234	1735	164	5994	815	550
M. apiaster	4625	3355	5024	2107	2733	5906	1828

Altitude of autumn migration

Distribution of altitudes of birds recorded during autumn migration at SNWF was reported in reports for 2008, 2009, 2010, 2011, 2012 and 2013 available at: http://www.aesgeoenergy.com/site/Studies.html. The same species were used in order to keep a standard comparative approach in autumn 2014.

In order to examine whether there has been a change in the altitudinal distribution of birds between the pre-construction and the operational periods we have calculated the average altitude per year of all species of diurnal migrants regularly passing through the wind farm territory in autumn. In this report, data on average altitude of flights by species for the autumn 2014 are added, in Table 4.

Table 4. Average flight altitude, by species, of diurnal migrants observed in territory of SNWF across seven autumn seasons, 2008-2014: the years when the wind farm was constructed are highlighted in grey.

Species	2008	2009	2010	2011	2012	2013	2014
A. brevipes	132	171	171	160	142	263	188
A. cinerea	201	239	263	386	190	344	341
A. gentilis	181	176	230	199	151	267	232
A. nisus	150	135	162	141	119	204	124
A. pennata	150	283	251	213	295	261	368
A. pomarina	244	273	234	234	241	353	279
B. buteo	165	199	206	197	158	278	215
B. rufinus	109	200	230	183	147	211	177
C. aeruginosus	158	139	235	150	128	222	201
C. ciconia	199	174	434	347	358	390	279
C. cyaneus	136	100		10		267	70
C. gallicus	256	144	258	242	218	229	269
C. macrourus	251	90	240	195	86	188	150
C. nigra	462	325	375	350	388	382	330

Species	2008	2009	2010	2011	2012	2013	2014
C. pygargus	196	115	285	106	79	209	144
F. subbuteo	97	119	161	161	127	131	181
F. tinnunculus	49	96	109	70	79	67	85
F. vespertinus	106	106	224	289	121	139	156
M. migrans	175	183	166	152	233	243	179
P. apivorus	320	175	268	283	204	342	290
P. haliaetus	314	208	224	433		400	133
P. leucorodia	433	285	667	317		317	
P. onocrotalus	100	159	417	400	265	263	271
Ph. carbo	180	179	277	271	254	265	285

No trend in the fluctuations of average altitude of the most numerous soaring bird species was registered after seven years autumn migration monitoring at SNWF, including one pre-construction and six post-construction seasons. The comparative analysis showed that there is no significant change in average flight altitudes of the 24 most numerous bird species regularly migrating through SNWF (Figure 5).

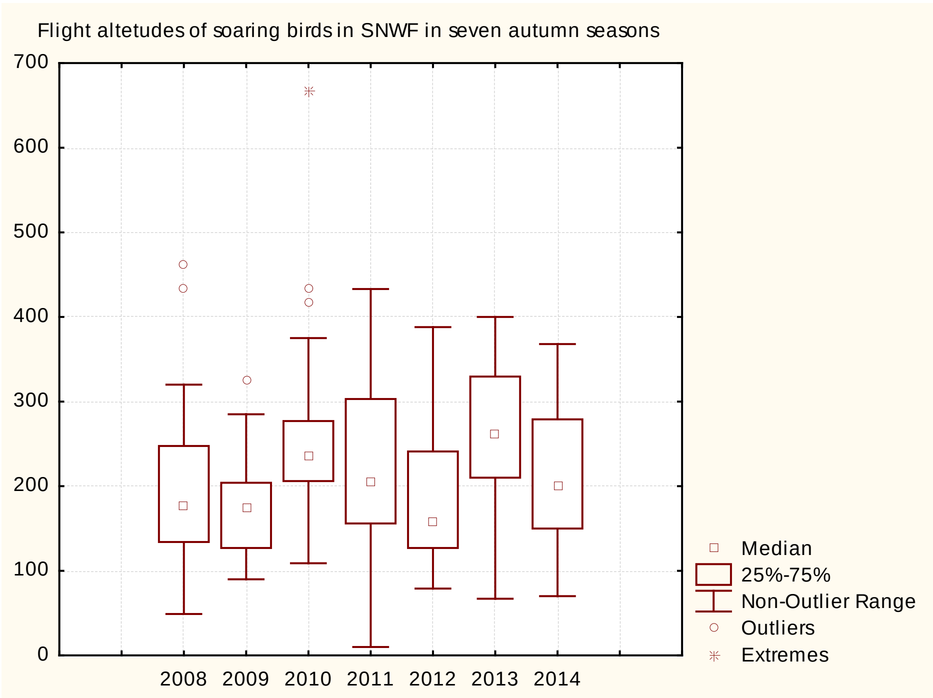


Figure 5. The median altitude of soaring bird migration in autumns of 2008 to 2014, with measures of variance. The species included in the calculations are presented in Table 4.

Observed flight altitudes of bee-eaters and swallows were analyzed despite the constraints on reliability imposed by visual observation, as mentioned earlier in the present report. Nevertheless, despite this caveat, it appeared that while the average observed flight altitude of bee-eaters and swallows varied widely across years there was no trend that could be attributable to the presence of SNWF (Table 5).

Table 5. Average altitude of flight during autumn migration of bee-eaters and swallows in the period 2008 – 2014 observed in SNWF.

Species	2008	2009	2010	2011	2012	2013	2014
H. rustica	28	51	66	19	37	32	35
M. apiaster	73	68	128	71	83	66	85
Average per year	56	61	121	65	71	63	67

These results suggest that changes in the flight altitude of soaring migrants, bee-eaters and swallows have had no consistent character across years and do not indicate any impact by SNWF. Most probably climatic factors are likely to be responsible for the fluctuations in average altitude of autumn migration in this seven year monitoring period. Regardless, any energetic consequences for migrants avoiding the turbines by way of a change in flight altitude will be immaterial to overall migratory energy budgets (Madsen et al. 2009, 2010) if they occur. Therefore there is no obvious evidence that SNWF may have resulted in changes in the behavior of passing migrating birds so far as flight altitude is concerned.

Direction of autumn bird migration

The mean recorded direction of the 24 species is presented in Table 7. It was already explained in previous reports why 2009 was apparently an exception because the observation points were moved northward in order to test an early warning system for approaching flocks of birds. Prevailing directions of autumn migration observed in all seven autumn seasons do not indicate changes in migratory direction through a response to SNWF in years when there was greater consistency in the location of observation points (i.e. excluding 2009: see above). The main direction in all years shows the guiding role of the coast line (See Figure 1 and Table 7).

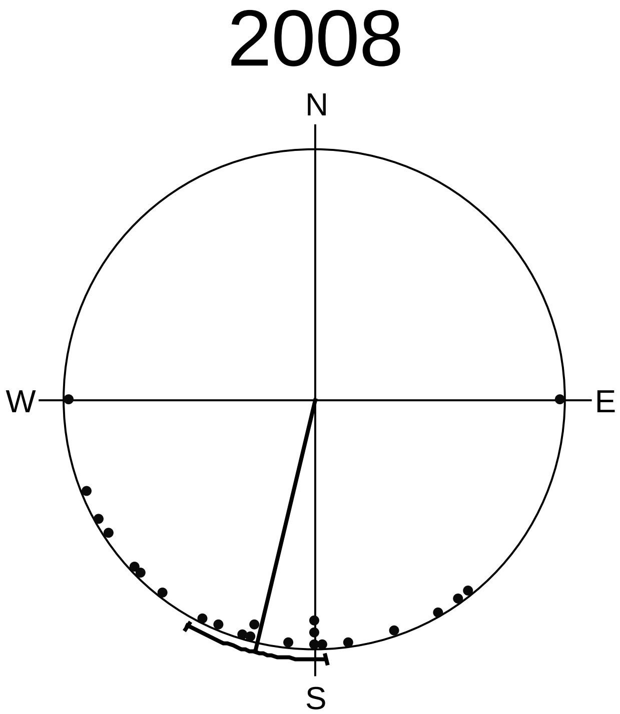
Table 7. Average observed flight direction of autumn migration by species in different years. Directions are given in degrees starting from 0 (North).

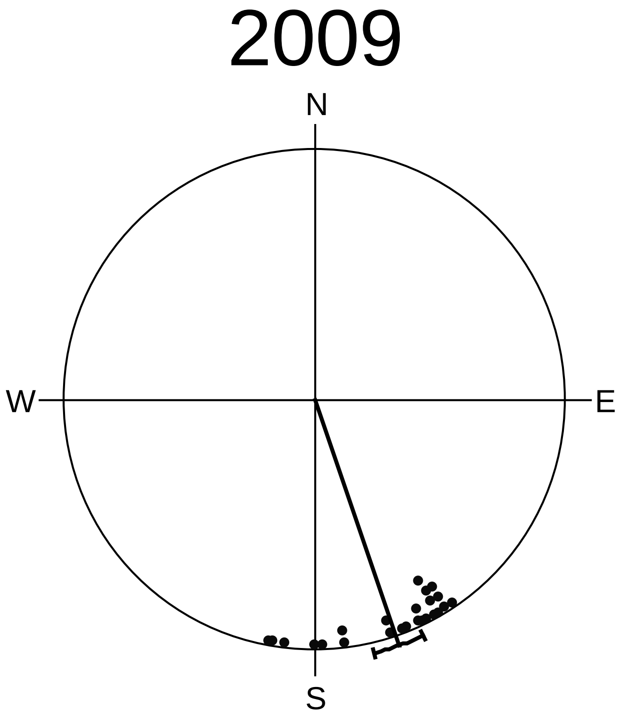
Species	2008	2009	2010	2011	2012	2013	2014
A. brevipes	172	151	185	175	179	191	156
A. cinerea	248	178	146	138	203	167	176
A. gentilis	195	162	171	180	149	181	163
A. nisus	218	155	186	193	174	185	164
A. pennata	180	150	182	165	216	184	212
A. pomarina	225	173	204	183	193	214	180
B. buteo	195	150	177	179	179	198	172
B. rufinus	150	158	227	186	188	158	119
C. aeruginosus	197	150	191	188	175	199	166
C. ciconia	207	154	209	210	209	216	181
C. cyaneus	90	180		225		188	180
C. gallicus	203	150	144	151	129	159	142
C. macrourus	141	154	180	231	109	210	144
C. nigra	270	191	225	180	231	205	163
C. pygargus	237	148	182	183	174	194	154
F. subbuteo	186	148	174	196	196	188	157
F. tinnunculus	144	148	177	161	191	156	153
F. vespertinus	180	159	177	204	218	206	169
M. migrans	241	153	211	207	189	192	210
P. apivorus	227	187	201	200	208	204	174
P. haliaetus	161	190	168	198	169	199	152
P. leucorodia	180	173	195	180		180	
P. onocrotalus		146	195	257	232	214	180
Ph. carbo	178	162	192	160	121	177	155

Table 8. Basic statistical parameters of empirical flight directions obtained from visual observations during five autumn seasons in SNWF territory for the 24 ‘core’ soaring bird species.

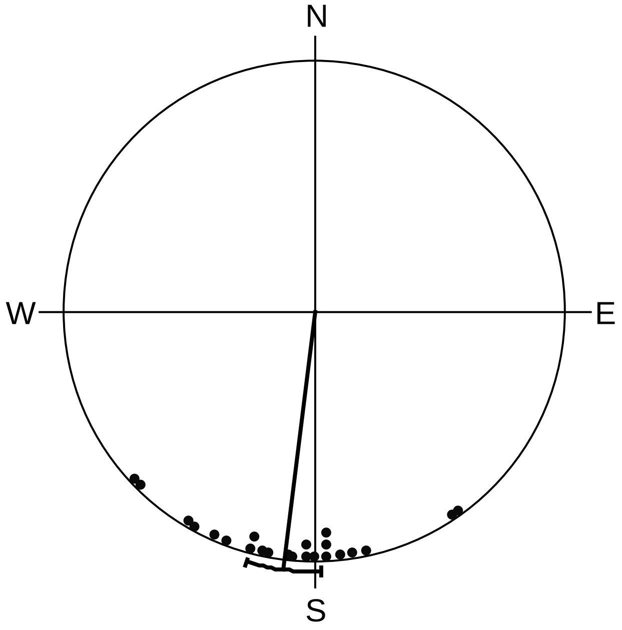
Variable	2008	2009	2010	2011	2012	2013	2014
Number of species	23	24	23	24	22	24	23
Mean Vector (μ)	193°	161°	186°	188°	184°	190°	166°
Length of Mean Vector (r)	0,8	0,96	0,93	0,90	0,85	0,95	0,94
Concentration	2,7	16,6	8,4	5,5	3,7	11,8	8,8
Circular Variance	0,21	0,03	0,06	0,09	0,14	0,95	0,05
Circular Standard Deviation	39,3°	14,2°	20,2°	25,5°	32,3°	17,1°	19,8°

The circular (compass) distributions of flight directions of soaring birds are presented in graphs below for each year (Figure 7).

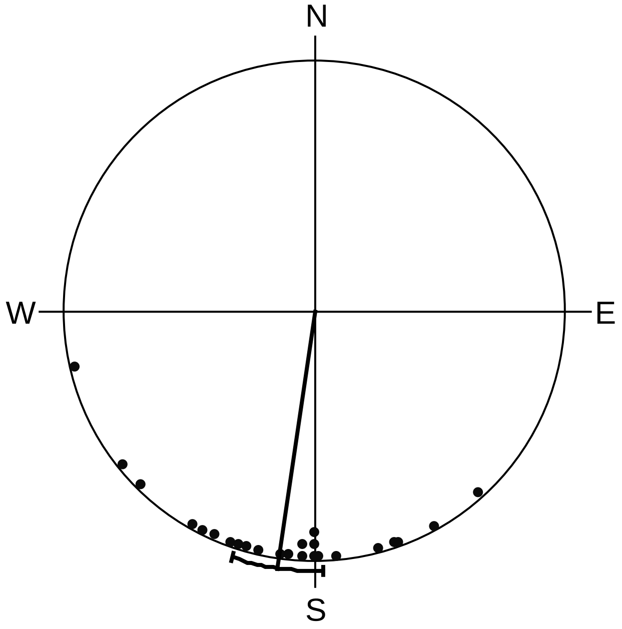




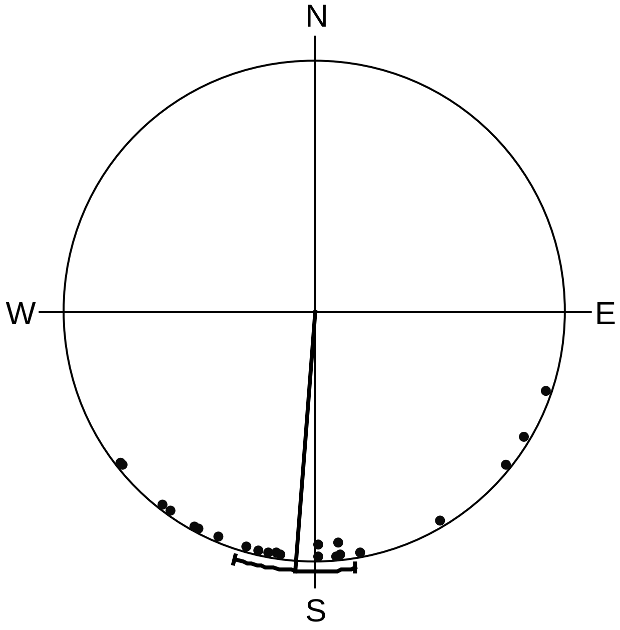
2010



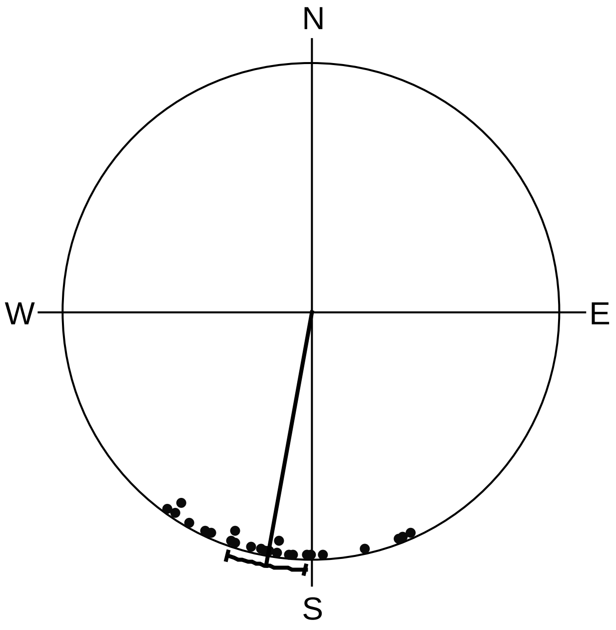
2011



2012



2013



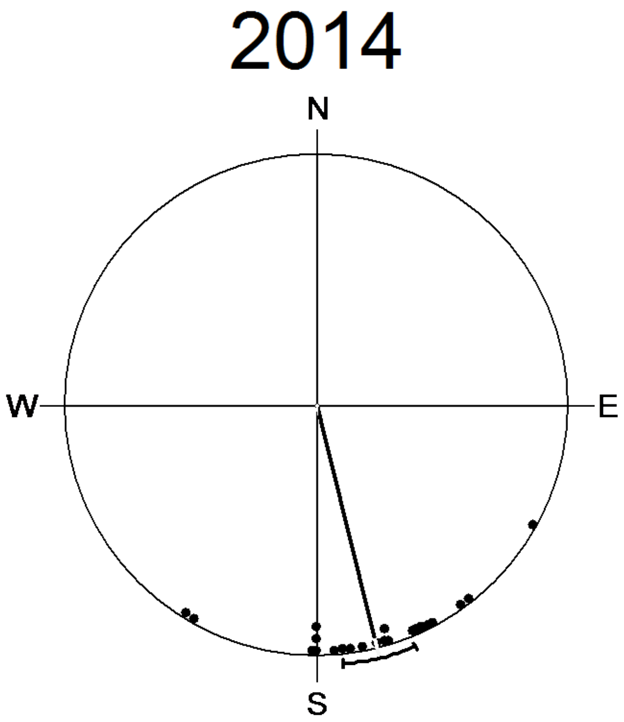


Figure 6. Graphical representations of the average flight directions of the 24 'core' soaring bird species by year: each record = 1 species (see Table 8).

The direction of migration in 24 of most common and numerous soaring birds observed at SNWF in the last seven years does not indicate any consistent annual deviation from the seasonal migratory direction after construction of SNWF. However, due to a shifting of the observation points to the north in 2009 we have expected to find a difference only in this year (see previous reports for details) and so the records of flight directions consequently differed in 2009. In 2014 mean direction of the same 24 most numerous species of soaring birds indicate that not only the location of observation points but also some other factors (species cooption and probably specific wind directions during the season) can explain much better seasonal deviations from the main direction of soaring bird migration across SNWF in last seven years. More formal statistical tests of these differences are given later in the present report. The current results do not suggest that birds were avoiding SNWF in one preferred direction.

Bearing in mind the limitations of visual observation described earlier in respect of smaller birds such as swallows and bee-eaters, analysis of the data for these birds may nevertheless serve to illuminate their behavior in SNWF. In order to reduce the level of subjective error in estimation of flight direction for species such as swallows and bee-eaters, which generally flew in dispersed flocks, the data were grouped in 16 (22.5 degree) sectors. Average results for the barn swallow and the bee-eater (most numerous species) are tabulated in Table 9.

Table 9. Average flight directions of barn swallows *H. rustica* and bee-eaters *M. apiaster* as observed in SNWF territory across seven autumn seasons.

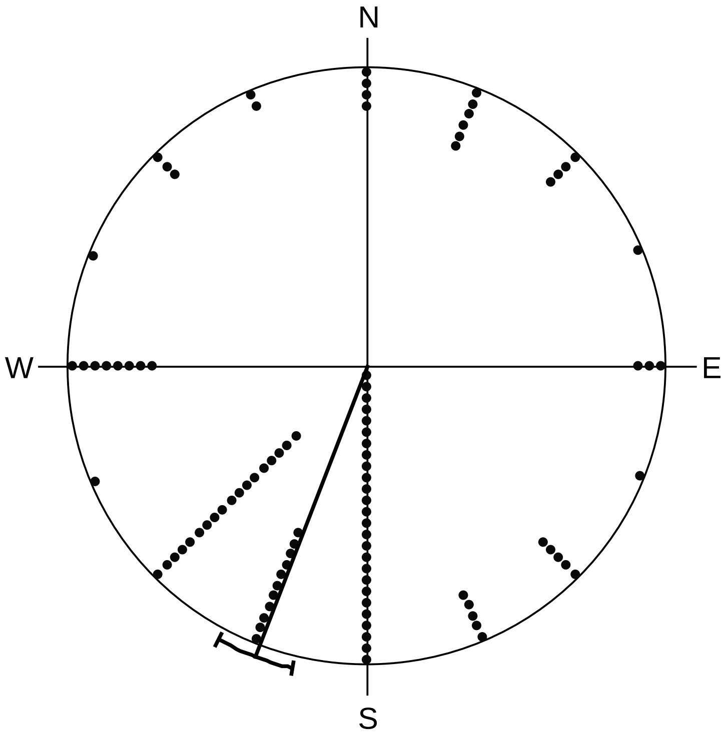
Species	2008	2009	2010	2011	2012	2013	2014
H. rustica	158	144	204	169	172	150	101
M. apiaster	191	142	192	186	187	189	177

Further analysis of bee-eater flight directions in seven years of autumn monitoring at SNWF is presented below through descriptive statistics (Table 10) and graphically (Figure 7).

Table 10. Basic statistical parameters of empirical flight directions obtained from visual observations during seven autumn seasons in SNWF territory for the bee-eater (*M. apiaster*).

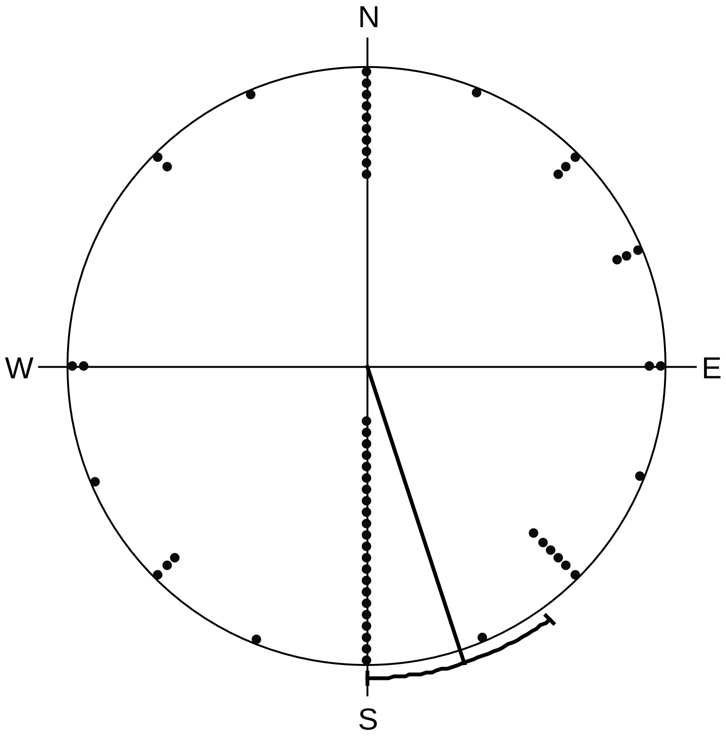
Variable	2008	2009	2010	2011	2112	2013	2014
Number of Observations	461	213	159	100	108	176	104
Data Grouped?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Group Width (& Number of Groups)	22,5° (16)	22,5° (16)	22,5° (16)	22,5° (16)	22,5° (16)	22,5° (16)	45° (8)
Mean Vector (μ)	201°	162°	199°	192°	199°	192°	190°
Length of Mean Vector (r)	0,5	0,3	0,8	0,8	0,6	0,8	0,6
Concentration	1,1	0,6	2,5	2,1	1,6	2,8	1,5
Circular Variance	0,5	0,7	0,2	0,2	0,3	0,2	0,3
Circular Standard Deviation	69,8°	89,1°	41,6°	47,5°	54,8°	38,6°	56,1°

2008

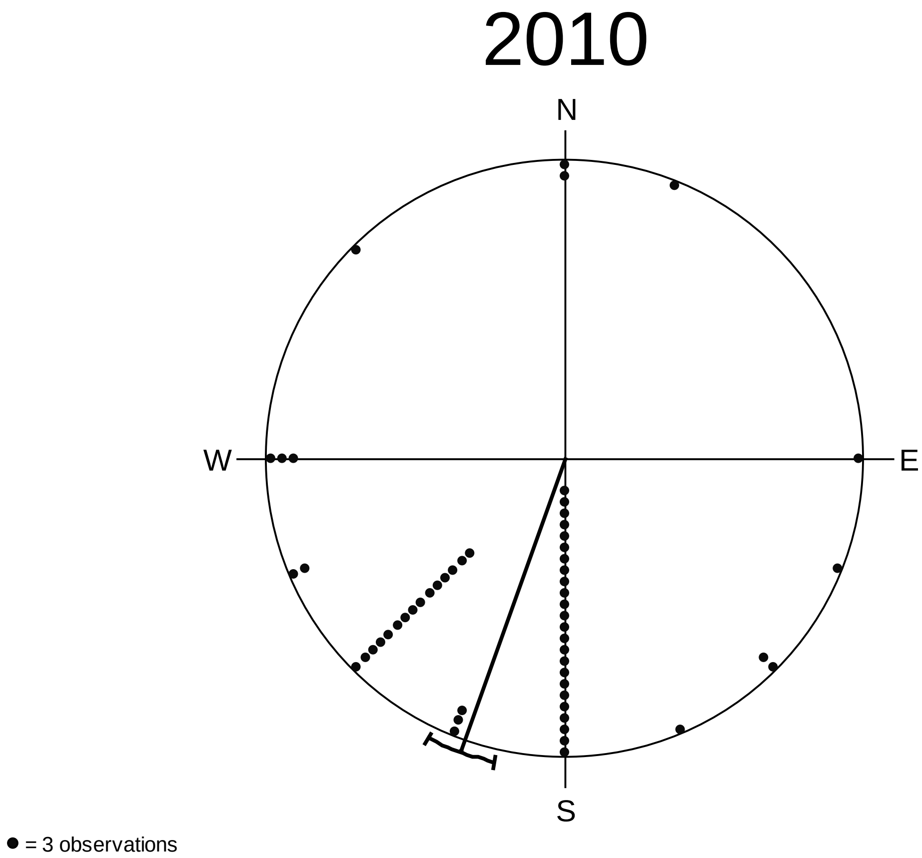


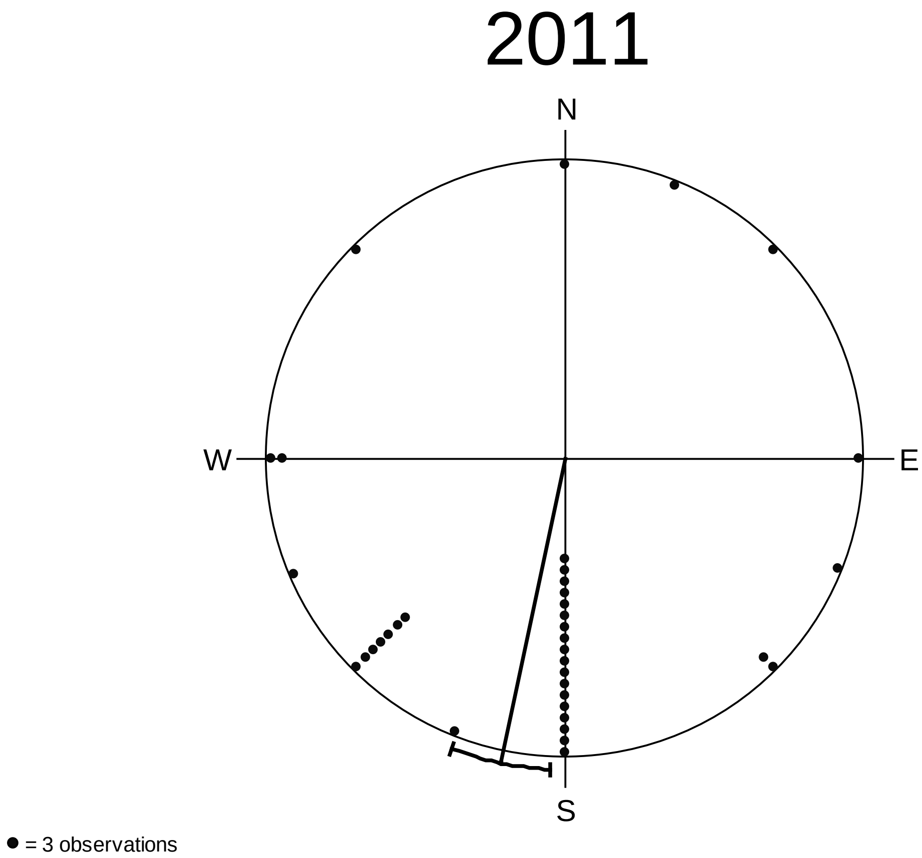
● = 5 observations

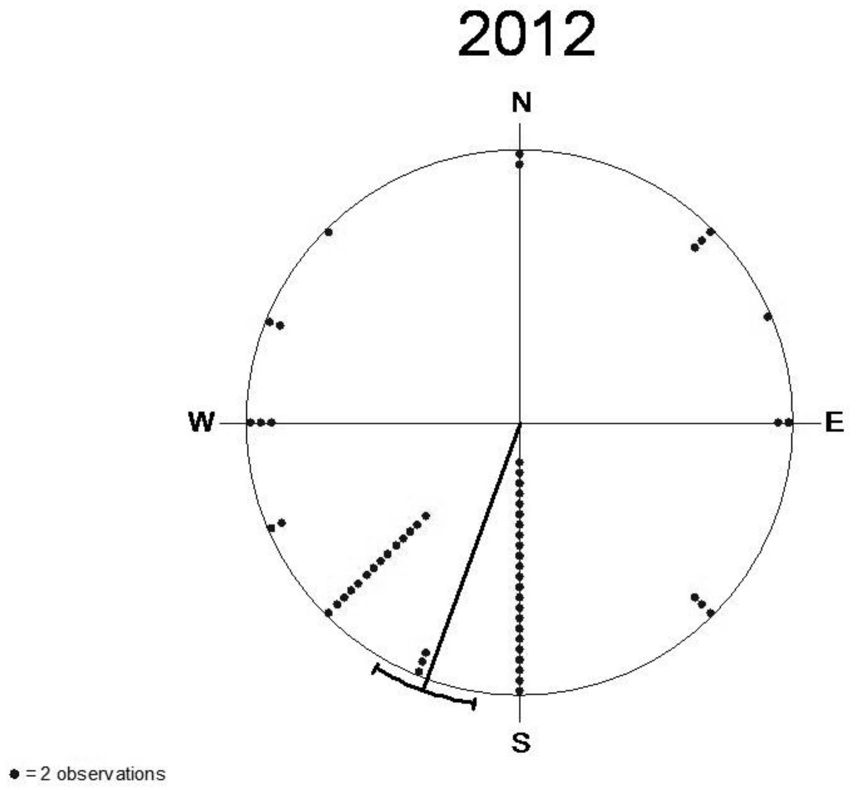
2009

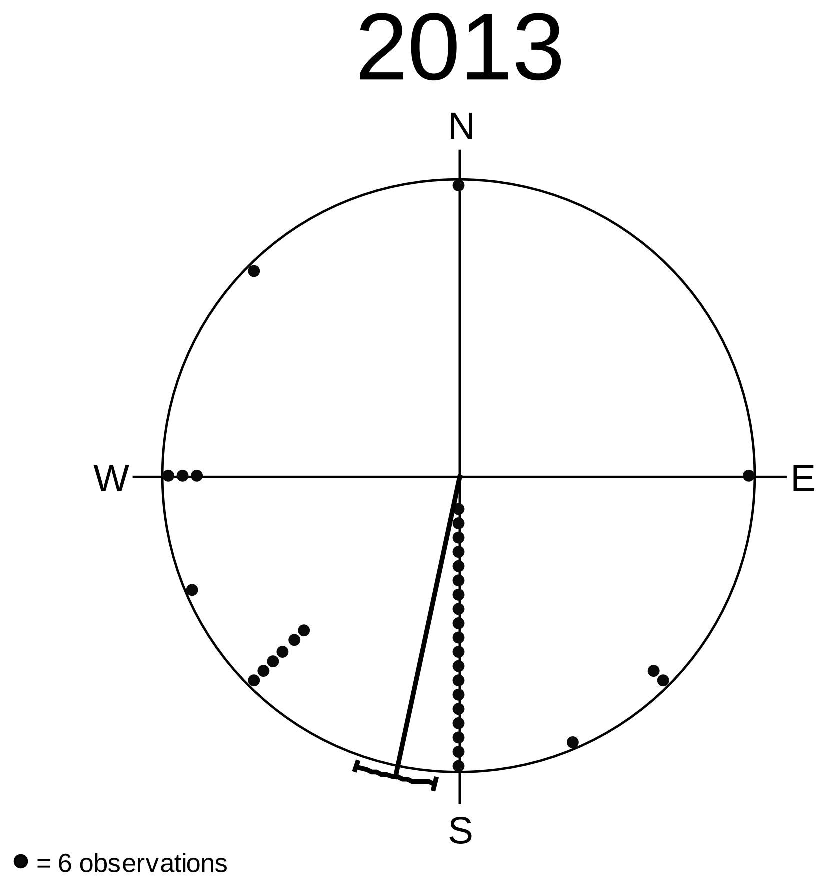


● = 4 observations


2010
N
W
E
S
● = 3 observations


2011
N
W
E
S
● = 3 observations


2012
N
W
E
S
= 2 observations


2013
N
W
E
S
= 6 observations

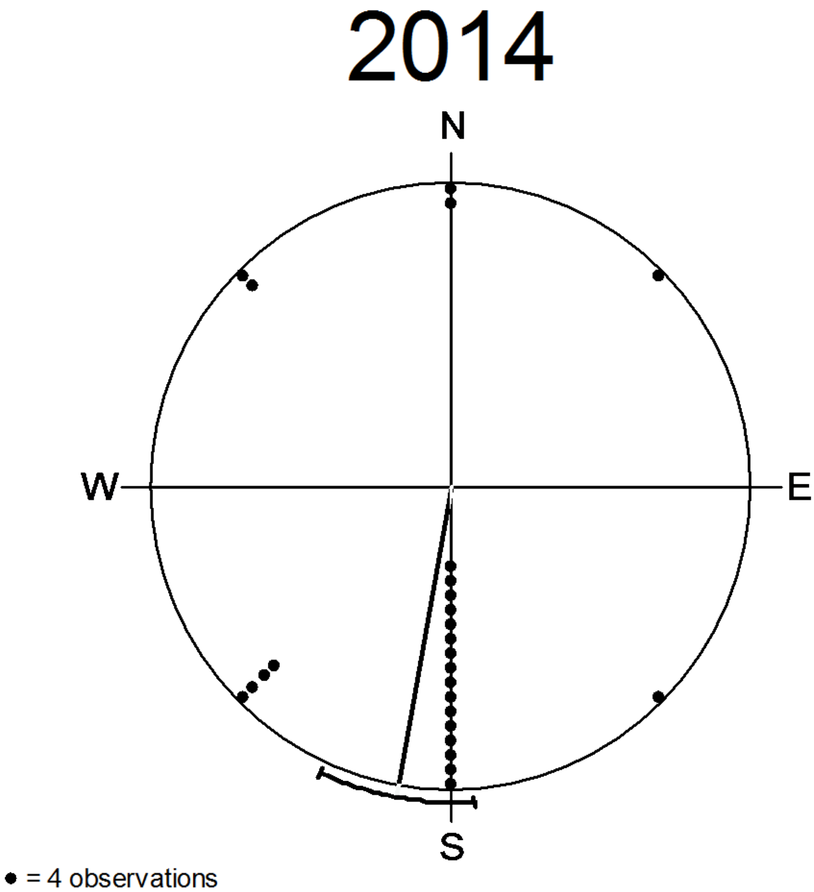


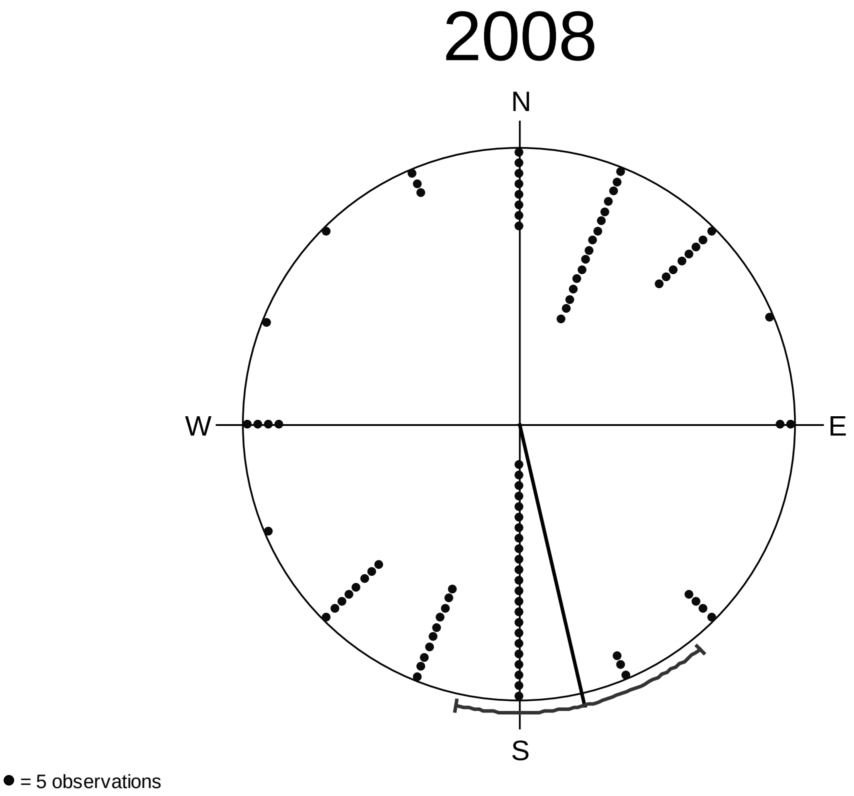
Figure 7. Graphical representations of the flight directions of bee-eaters by year.

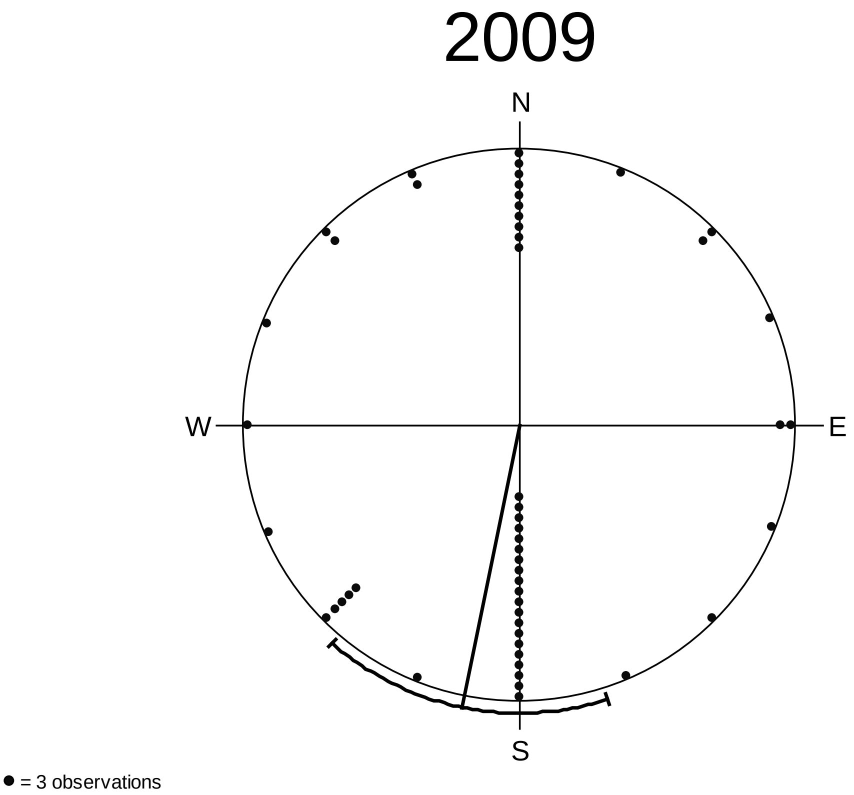
In general all the data we have from observations of Barn Swallows for seasons 2008 – 2014 indicate feeding activity instead of active migratory flight through SNWF during autumn monitoring period. More details about these feeding movements are presented as descriptive statistics (Table 11) and graphically (Figure 8).

Table 11. Basic statistical parameters of empirically obtained flight directions of Barn Swallows after standard visual observations in seven autumn seasons at SNWF (for details see the methods section).

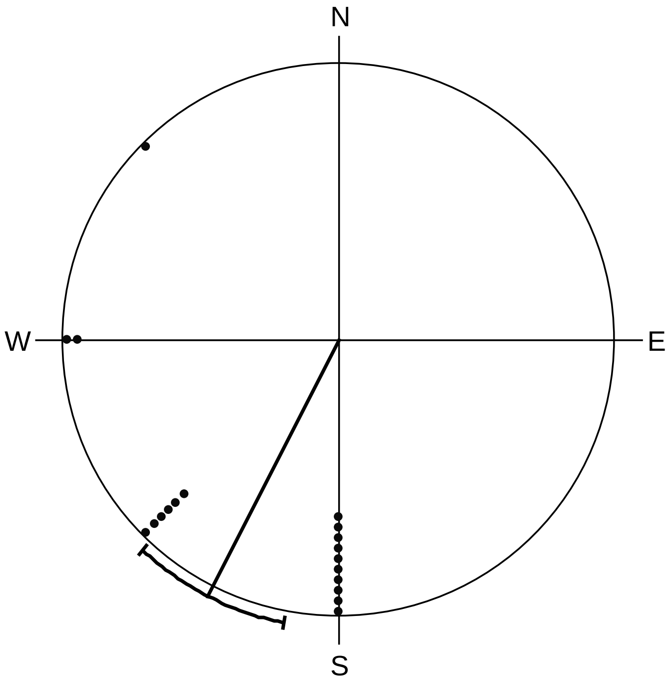
Variable	2008	2009	2010	2011	2012	2013	2014
Number of Observations	433	132	19	8	48	34	8
Group Width (& Number of Groups)	22,5° (16)	22,5° (16)	45° (8)	45° (8)	22,5° (16)	22,5° (16)	No
Mean Vector (μ)	167°	191°	207°	173°	174°	200°	70°
Length of Mean Vector (r)	0,147	0,233	0,822	0,624	0,37	0,6	0,4
Concentration	0,297	0,479	3,155	1,455	0,797	1,511	0,6
Circular Variance	0,853	0,767	0,178	0,376	0,63	0,4	0,5

Variable	2008	2009	2010	2011	2012	2013	2014
Circular Standard Deviation	112,186°	97,802°	35,9°	55,655°	80,764°	57,875°	76°

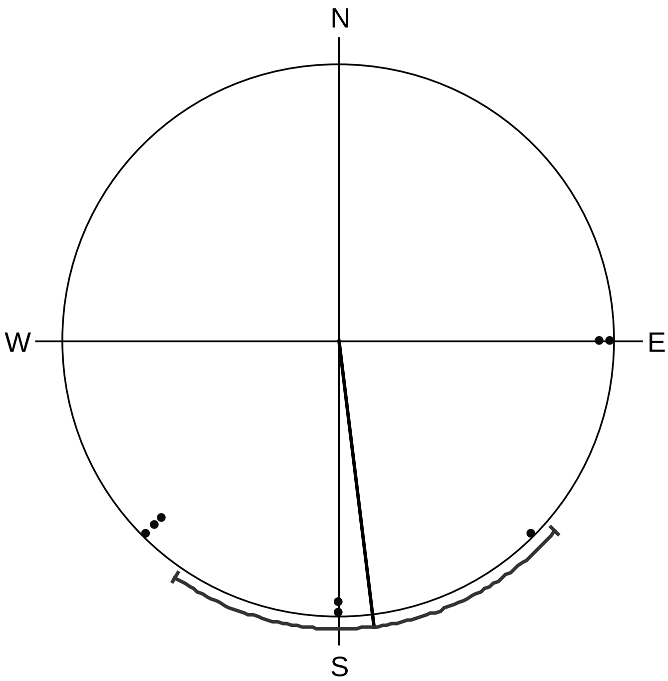




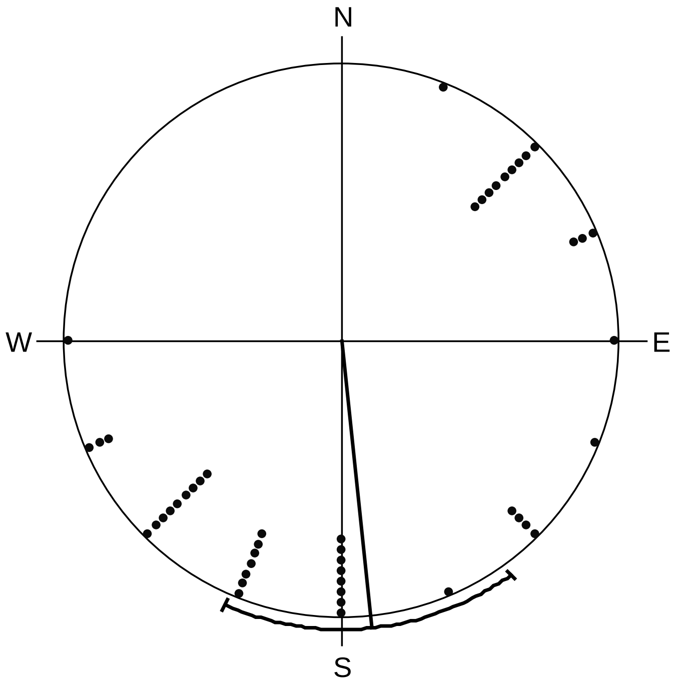
2010



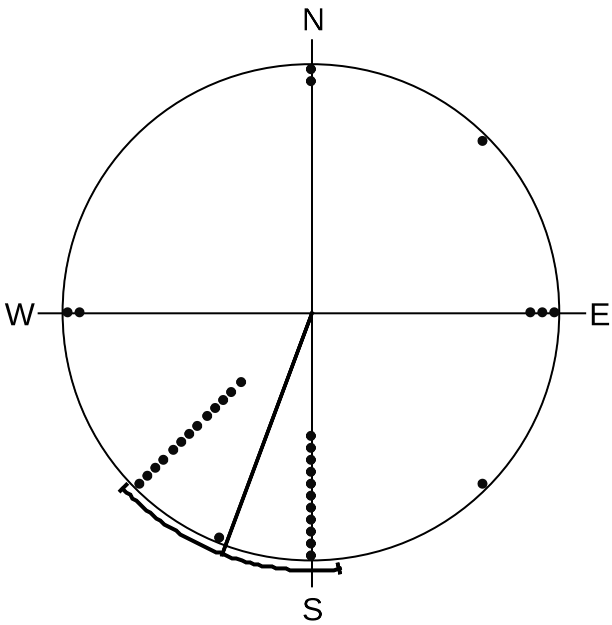
2011



2012



2013



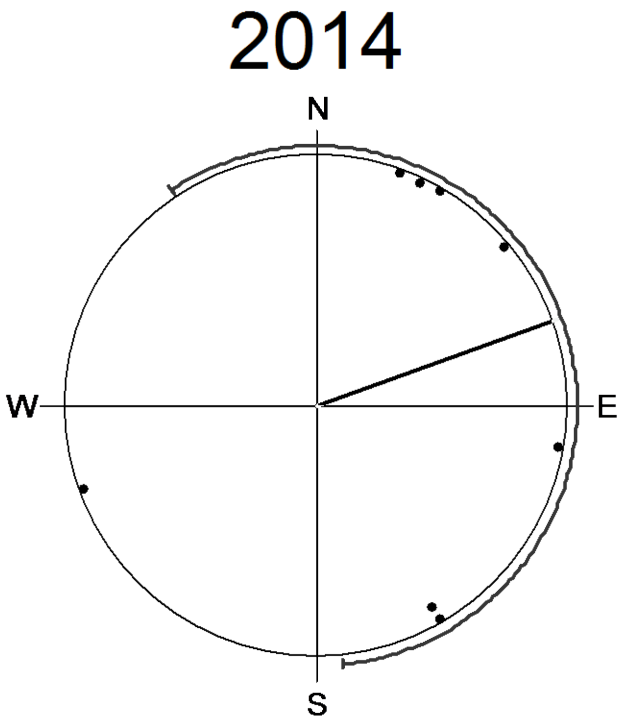


Figure 8. Graphical representations of the flight directions of Barn Swallows by year.

Circular statistics of observed directional distributions of Bee-eaters to those obtained from soaring birds in the same periods. Barn Swallow flight directions were relatively less concentrated which reflected the feeding behavior of the species during migration, when feeding activity around observation points lead to registrations in multiple directions that did not always correspond with the broad seasonal migration direction in autumn.

The pooled direction of autumn migration for all species across the five years of consistent observation points in the period since SNWF has been operational does not deviate markedly from a southerly autumn migratory direction and is in line with the guiding effect of the coast line, as expected in the absence of the wind farm, and the location of study area (Figure 9).

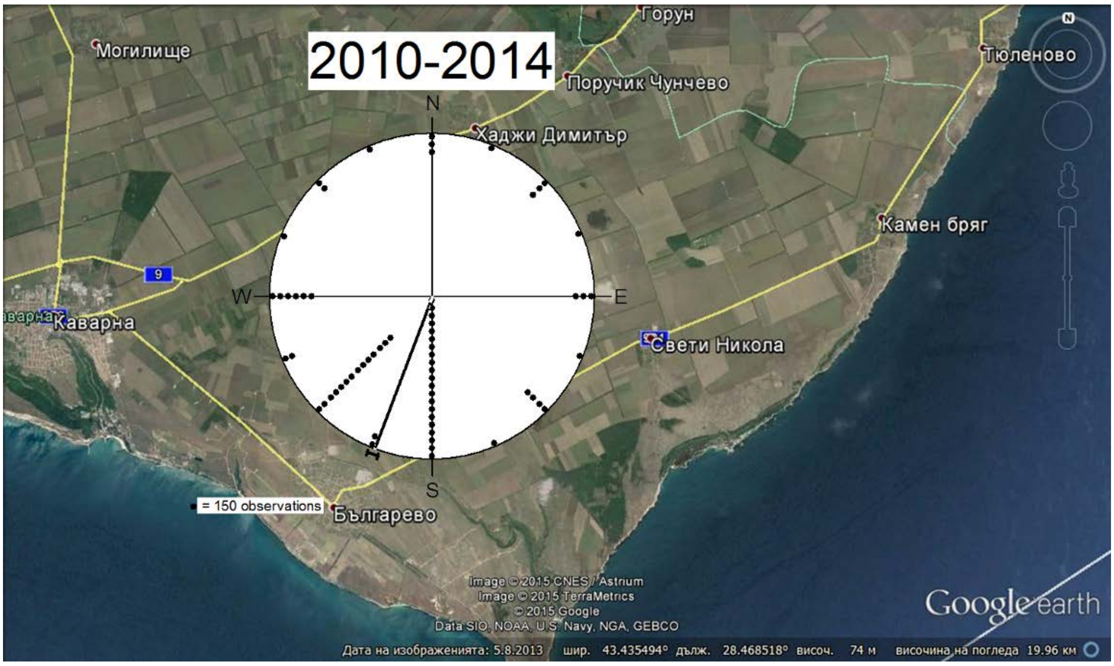


Figure 9. Pooled data on direction of autumn migration of all species across the five years of operational period (2010 – 2014) of SNWF as observed during the monitoring.

There is no evidence under the scale and form of analysis for a major directional change in the flight orientation behavior of autumn migrants (macro-avoidance) as a result of the wind farm operation. At the scales considered, birds that were observed to enter the vicinity of the wind farm did not demonstrate any macro-avoidance of the turbines which could thereby be considered as a change of migratory direction and, consequently, contribute to a major change in migratory route or any detrimental effect on energy budgets.

Spatial and temporal distribution of observed ‘major’ influxes of soaring migrants and Turbine Shutdown System

In the autumn 2014, intensive soaring bird migration was observed mainly in the standard monitoring period 15 August – 30 September defined in previous reports with a peak period in August (Fig. 10). Prevailing wind directions in autumn 2014 were N – NE; the same as in every previous autumn of the study (Fig.11). Again as in previous years, westerly winds, which bring periodic influxes of soaring migrants swept easterly from the main Via Pontica migration route (Fig. 1) were infrequent (Fig. 11, 12).

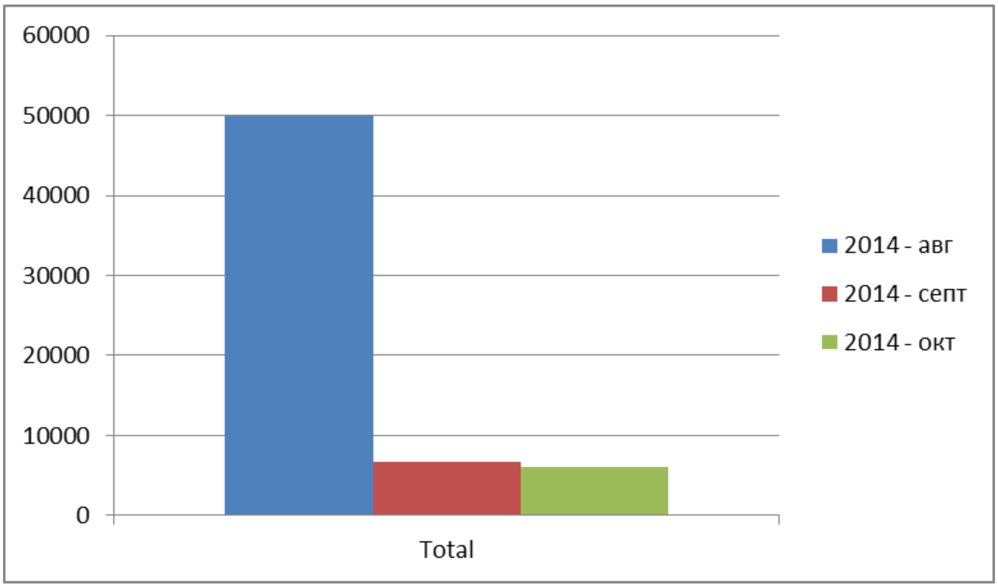


Figure 10. Distribution of all registrations of birds during the autumn season 2014: August (blue), September (red) and October (green).

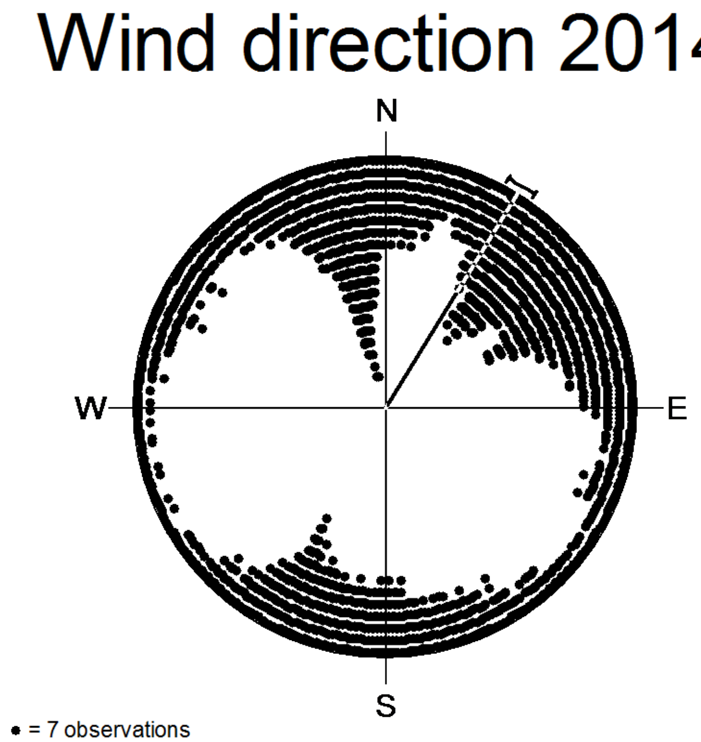


Figure 11. The distribution of wind directions in the period 12 August – 31 October 2014 measured in 10 minute intervals

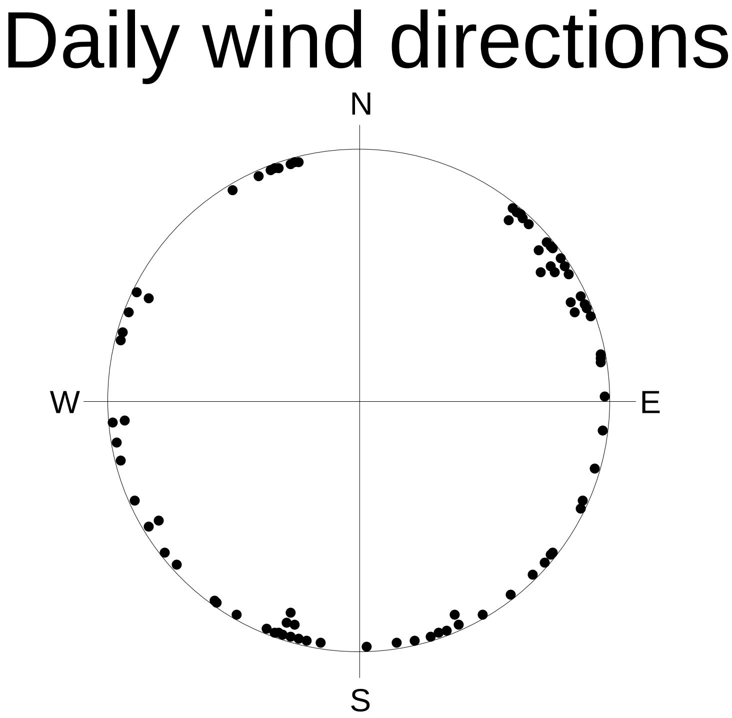


Figure 12. Daily wind directions as measured in SNWF during the period 12 August – 31 October 2014

Westerly winds in certain periods of autumn 2014 resulted in relatively greater numbers of soaring migrants observed in flocks, on: 12th, 13 th, 17 th, 18 th, 22 th, 28 th August and 24 th and 28 th September (Table 12 and Fig.13).

Table 12. Daily wind direction and proportion of birds passing throught SNWF in the same day.

Date	**Average of WD**	**Proportion of all observed birds**
12.Aug.	199	6
13. Aug.	190	4
14. Aug.	106	0
15. Aug.	172	5
16. Aug.	194	2
17. Aug.	285	6
18. Aug.	233	14
19. Aug.	196	0
20. Aug.	156	0

Date	Average of WD	Proportion of all observed birds
21. Aug.	178	0
22. Aug.	129	0
23. Aug.	81	0
24. Aug.	192	4
25. Aug.	142	3
26. Aug.	114	0
27. Aug.	201	0
28. Aug.	198	33
29. Aug.	50	0
30. Aug.	58	0
31. Aug.	59	0
1. Sept.	51	0
2. Sept.	56	0
3. Sept.	65	0
4. Sept.	42	1
5.Sept.	39	1
6.Sept.	53	0
7.Sept.	135	0
8.Sept.	286	1
9.Sept.	257	0
10.Sept.	216	0
11.Sept.	156	0
12.Sept.	90	0
13.Sept.	45	0
14.Sept.	58	0
15.Sept.	51	0
16.Sept.	42	0
17.Sept.	82	0
18.Sept.	150	1
19.Sept.	163	0
20.Sept.	210	0
21.Sept.	198	0

Date	Average of WD	Proportion of all observed birds
22.Sept.	203	0
23.Sept.	297	0
24.Sept.	247	1
25.Sept.	128	0
26.Sept.	297	0
27.Sept.	342	0
28.Sept.	344	1
29.Sept.	376	1
30.Sept.	240	0
1.Oct.	160	0
2.Oct.	71	0
3.Oct.	69	0
4.Oct.	97	0
5.Oct.	40	0
6.Oct.	79	0
7.Oct.	117	0
8.Oct.	56	0
9.Oct.	66	0
10.Oct.	56	0
11.Oct.	68	0
12.Oct.	68	0
13.Oct.	167	0
14.Oct.	196	0
15.Oct.	198	1
16.Oct.	265	0
17.Oct.	266	0
18.Oct.	292	0
19.Oct.	132	0
20.Oct.	216	0
21.Oct.	240	0
22.Oct.	229	0
23.Oct.	161	0

Date	Average of WD	Proportion of all observed birds
24.Oct.	261	1
25.Oct.	40	0
26.Oct.	339	0
27.Oct.	340	5
28.Oct.	336	0
29.Oct.	345	0
30.Oct.	330	1
31.Oct.	346	0

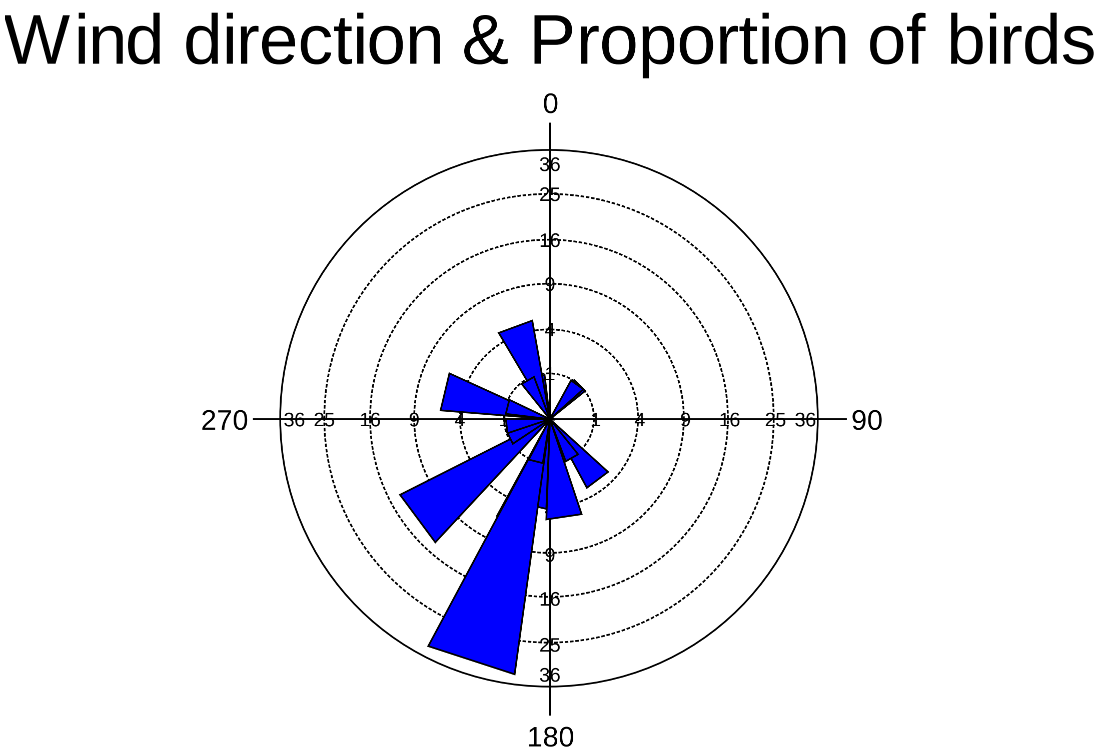


Figure 13. Correlation of the observed proportions of migrating birds under simultaneously measured wind directions. CIRCULAR-LINEAR CORRELATION Wind direction & Proportion of birds: r = 0,259, p= 0,006

The Turbine Shutdown System (TSS) probably contributed to a reduced risk of collision during all years of operation within infrequent periods of intensive soaring bird migration and provided a safety mechanism to reduce collision risk for single birds and flocks of endangered bird species. The data on the number of turbine stops under TSS in autumn 2014 with respect to the major observed flocks and single birds with conservation value are presented in Table 13.

Table 13. List of observed 'major' influxes of soaring migrants in autumn 2014 in or over SNWF. See Figure 14 for locations of wind turbine groups and individual turbines.

Date	**Stop**	**Start**	**Species**		**Number**	**Wind Turbine Groups**
12.08.2014	15:30	15:50	*Ciconia ciconia*	White stork	850	F
12.08.2014	15:30	20:15	*Ciconia ciconia*	White stork	550	T44,T43, T29
12.08.2014	16:15	18:30	*Ciconia ciconia*	White stork	610	F
12.08.2014	16:15	20:15	*Ciconia ciconia*	White stork	550	T42
13.08.2014	10:05	11:30	*Ciconia ciconia*	White stork	550	T43, T44
13.08.2014	10:08	11:30	*Ciconia ciconia*	White stork	930	F
13.08.2014	10:16	11:30	*Ciconia ciconia*	White stork	930	E
13.08.2014	11:58	12:08	*Ciconia ciconia*	White stork	90	F
17.08.2014	14:05	14:30	*Pelecanus onocrothalus*	White pelica n	350	A
17.08.2014	14:07	14:30	*Pelecanus onocrothalus*	White pelica n	350	A,B,C,D,E, F
17.08.2014 .	17:44	18:16	*Ciconia ciconia*	White stork	1000	F
18.08.2014	08:10	08:18	*Ciconia*	White	30	C

Date	Stop	Start	Species		Number	Wind Turbine Groups
			ciconia	stork		
18.08.2014	09:45	10:20	*Pelecanus onocrothalus*	White pelican	200	A,B
18.08.2014	10:18	10:32	*Pelecanus onocrothalus*	White pelican	7	C
18.08.2014	08:02	08:12	*Ciconia ciconia*	White stork	100	F
18.08.2014	08:17	08:24	*Ciconia ciconia*	White stork	400	F
18.08.2014	09:14	09:25	*Ciconia ciconia*	White stork	77	F
18.08.2014	06:11	06:17	*Ciconia ciconia*	White stork	80	D
18.08.2014	07:08	07:20	*Ciconia ciconia*	White stork	140	D,E
18.08.2014	08:19	08:36	*Ciconia ciconia*	White stork	78	F
18.08.2014	08:46	08:51	*Ciconia ciconia*	White stork	15	F
18.08.2014	10:04	10:11	*Ciconia ciconia*	White stork	80	F,E
22.8.2014	10:44	11:00	*H. albicilla*	White-tailed eagle	1	D, E
22.8.2014	10:44	10:50	*H. albicilla*	White-tailed eagle	1	F
28.8.2014	08:48	08:58	*C. ciconia*	White Stork	1300	A
28.8.2014	10:15	10:20	*C. ciconia*	White	2000	A

Date	Stop	Start	Species		Number	Wind Turbine Groups
				Stork		
28.8.2014	09:10	09:20	*C. ciconia*	White Stork	1300	34, 35, 33
28.8.2014	08:48	08:58	*C. ciconia*	White Stork	1300	A
28.8.2014	09:50	09:52	*C. ciconia*	White Stork	300	B
13.09.2014	12:50	12:55	*Ciconia ciconia*	White stork	18	A
24.09.2014	09:20	09:25	*Ciconia nigra*	Black stork	4	B
28.9.2014	08:35	08:41	*P. onocrotalus*	White pelica n	58	E
28.09.2014	08:20	08:35	*Ciconia nigra*	Black stork	5	B, D

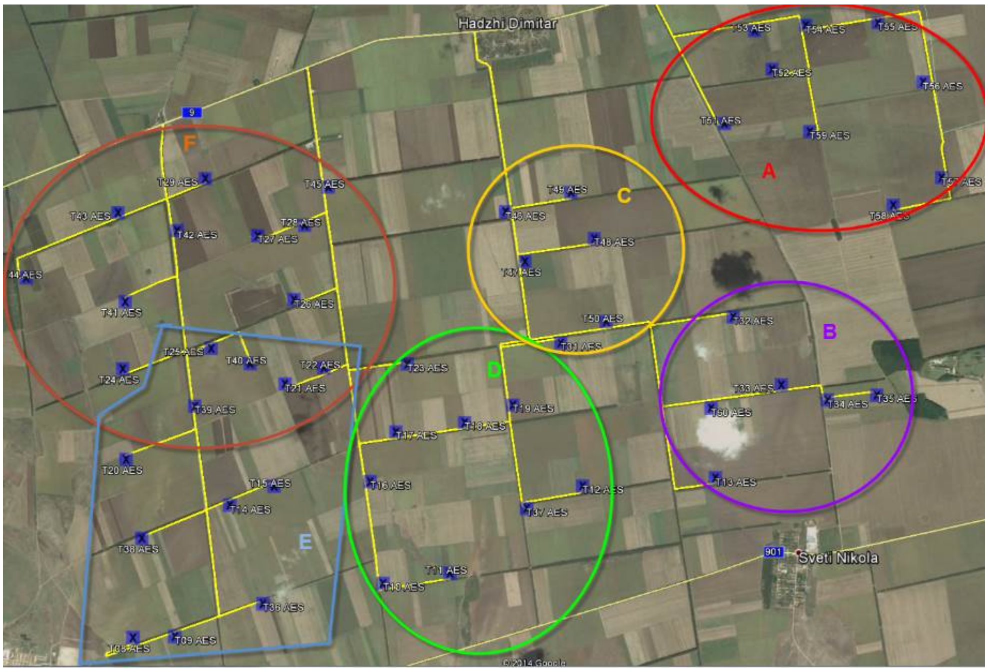


Figure 14. The groups of turbines associated with the numbers of turbine stops during autumn season of 2014 as described in Table 12, column 'Wind Turbine Groups'.

The biggest flock observed in autumn 2014 was a flock of 2000 White Storks in SNWF (in sector A) on August 28th. The latest flocks of migrants were registered on 28th September when 58 White Pelicans and 5 Black storks crossed SNWF.

The majority of flocks of soaring migrants as well as single birds of target species concerning the conditions of the TSS were observed under westerly wind conditions. This confirms previous data analyses from other years, presented in earlier reports (http://www.aesgeoenergy.com/site/Studies.html) indicating that SNWF is situated to the east of the main migratory flyway and so only occasionally hosts major numbers of migrants when -non prevailing- westerly wind conditions shift birds from the flyway. As is described later in this report, these numbers are consistently lower than stated by BSPB before SNWF was approved for operation.

Collision victim monitoring

It is well known that searches for victims of collision with operational wind turbines fail to find all dead birds, for several reasons, with the two principal factors being searcher efficiency (searchers fail to find all dead birds) and removal/disappearance of dead birds before the searcher can potentially find them. Accounting for these two potential biases can substantially improve estimates of collision mortality at operational wind farms derived from searches around turbine bases. Staged trials are typically undertaken in order to provide for such correction.

To repeat previous trials of carcass persistence and searcher efficiencies (in 2009 and 2010) a further trial was conducted in autumn 2014. Twenty-five fresh hen carcasses were positioned at random around five turbines on 19 August 2014: T25 (6), T43 (5), T47 (6), T51 (4), T54 (4). All carcasses had been checked by a veterinarian doctor and were confirmed free of diseases. The five turbines were selected as being in habitats representative of the habitat composition of the whole wind farm. Tests of searcher efficiency and carcass persistence were combined such that the searcher efficiency trial was conducted on the same day as the carcasses were placed (before any had disappeared or were removed) and the carcasses were then monitored for presence or remaining signs (after an initial check the following day) at 2 – 3 day intervals thereafter until no signs of the carcasses remained.

Searcher efficiency trial: 2014 results

Three ornithologists that carry out the majority of the systematic carcass searches at SNWF participated in the searcher efficiency trials. The searchers were unaware of the precise locations of the carcasses or the number that had been placed around each turbine, but were aware that they were being tested and that the surroundings of five turbines comprised the test area. The search protocol was otherwise similar to those conducted for carcasses that may have resulted from collision with turbine blades; such that transects were walked on 20 m intervals over an area of 200 x 200 m around a turbine during each search by each searcher. The trials were conducted on the same day as the carcasses were placed and all 25 hens were in place (available to be found) at the time of searching. The results are presented in Table 14.

Table 14. Summary of results of searcher efficiency trial.

		Number found by searcher			
Turbine	Number placed	Ivailo Raikov	Kiril Bedev	Viktor Vasilev	Overall % found by turbine
51	4	3	4	4	91.7%
54	4	4	4	4	100%
47	6	5	5	6	88.9%
25	6	5	6	4	83.3%
43	5	1	3	1	33.3%
					Mean
Searcher efficiency		72.0%	88.0%	76.0%	78.7%

The efficiency of the three individual searchers ranged from 72 – 88 %, with an average of 79 %. It was apparent that all three searchers had the greatest difficulty in detecting the carcasses around T43 because of the relatively higher and denser vegetation around this turbine (Table 13). Excluding this turbine would have resulted in an average efficiency across the three searchers of 90%.

Searcher efficiency trial: comparison with previous SNWF trials

Previous similar trials were conducted at SNWF in 2009 (at T20, T21, T27, T51, T54) and 2010 (at T25, T43, T49, T51, T54), on 6 September 2009 and 20 August 2010. In 2009 a single searcher was tested for efficiency and carcasses involved both hens and pigeons, with an overall efficiency of 83.3% (11 hens and 7 pigeons 'available to be found'). Efficiency for hens only was 72.7%. In 2010 there were 19 hens available to be found and the single searcher tested had a finding efficiency of 89.5%.

Overall, the results from 2014 were not markedly different from previous years, being substantially within the range of previous tests of searcher efficiency. If all tests (and including pigeons in 2009) are combined then the mean efficiency has been 81.8% (range 72.0% to 89.5%, n = 5). Given the potential influential factors on efficiency (e.g. searcher experience/skill and – notably – habitat being searched) and that these metrics are inevitably low in sample size in such exercises, it is difficult to justify any further analysis. Nevertheless, since these trials function to calibrate potential mortality rates from searches for strike fatalities through blade collision then because both searcher experience/skill and the habitat searched were correspondingly representative then this tends to remove a need for such further analysis. The absence of any radically different results from the trials across years does generate some confidence through consistency. However, there are constraints in the study design especially in the necessity that all searchers were aware that they were being tested, and that all carcasses had just been placed and so had not deteriorated: the severe shortage of 'naturally' occurring carcasses in the wind farm necessitated a staged trial. The searchers' knowledge that they were being tested and so were more attentive could have made them more efficient than during the routine searches for genuine collision victims.

Carcass removal rate trial: 2014

All 25 hen carcasses were still present for the first three days after their placement and only started to disappear (be removed e.g. by scavengers) thereafter (Table 15). The persistence of carcasses varied between turbine locations, with those around T47 disappearing rapidly beyond day 3 after their placement (a pack of feral dogs was present in this part of the wind farm). As in a previous SNWF trial (2009), at one plot (T25) carcasses disappeared due to agricultural activities (ploughing). Overall, at day six after placement seven, 48%, of the carcasses remained, and at day 17 there were six, 24%, remaining. All signs of any carcass had gone by day 28.

Table 15. Persistence of placed hen carcasses by turbine plot and date in the 2014 carcass removal trial.

Date	Day	T51	T54	T47	T25	T43	Total	% present
19/08/2014	0	4	4	6	6	5	25	100
20/08/2014	1	4	4	6	6	5	25	100
22/08/2014	3	4	4	6	6	5	25	100
25/08/2014	6	4	2	2	2	2	12	48
27/08/2014	8	4	2	0	1	1	8	32
29/08/2014	10	4	2	0	1	1	8	32
01/09/2014	13	4	2	0	1	1	8	32
03/09/2014	15	3	2	0	1	0	6	24
05/09/2014	17	3	2	0	1	0	6	24
08/09/2014	20	0	2	0	0	0	2	8

Date	Day	T51	T54	T47	T25	T43	Total	% present
10/09/2014	22	0	2	0	0	0	2	8
12/09/2014	24	0	2	0	0	0	2	8
15/09/2014	27	0	1	0	0	0	1	4

Carcass removal rate trial: comparison with previous SNWF trials

Compared with previous trials at SNWF in 2009 and 2010, the 2014 trial indicated that hen carcasses were not removed as quickly in the days immediately after placement, and several persisted for longer after 10 – 14 days (Fig. 15). The overall carcass persistence function from the three SWNF trials is not too dissimilar (perhaps remarkably) from that presented by Smallwood (2007) based on a much lower sample size (n = 14, *cf* n = 65 from SNWF trials) from USA studies of “chickens and game hens” (Fig. 16).

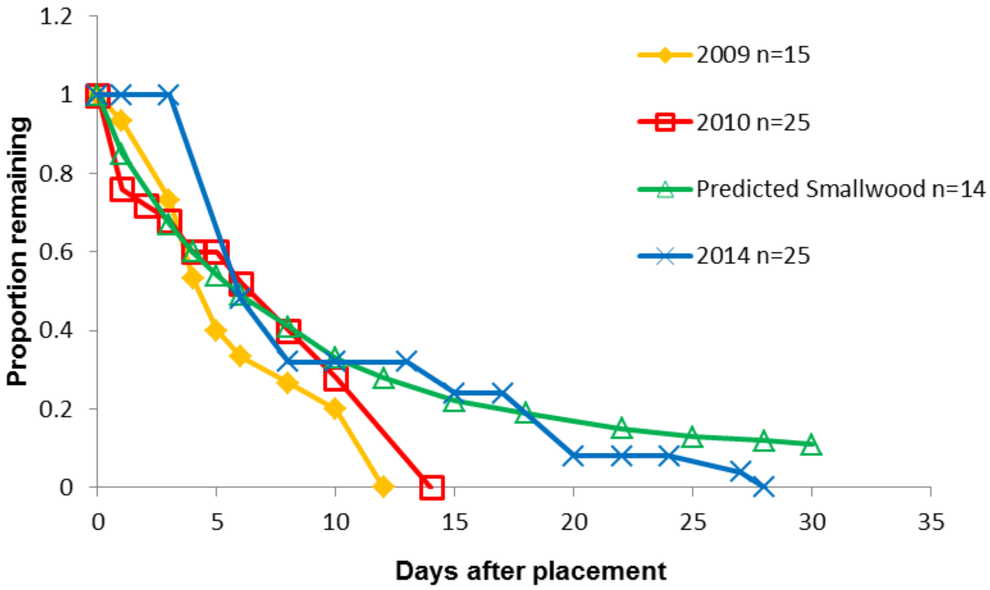


Figure 15. The rate of disappearance of hen carcasses in autumn carcass persistence trials at SNWF (2009, 2010, 2014) compared with the rate predicted by Smallwood (2007) which assumed a “steady state frequency of collisions” from a relatively small sample of “chickens and game hens” derived from studies in the USA (values taken from Smallwood’s [2007] Appendix).

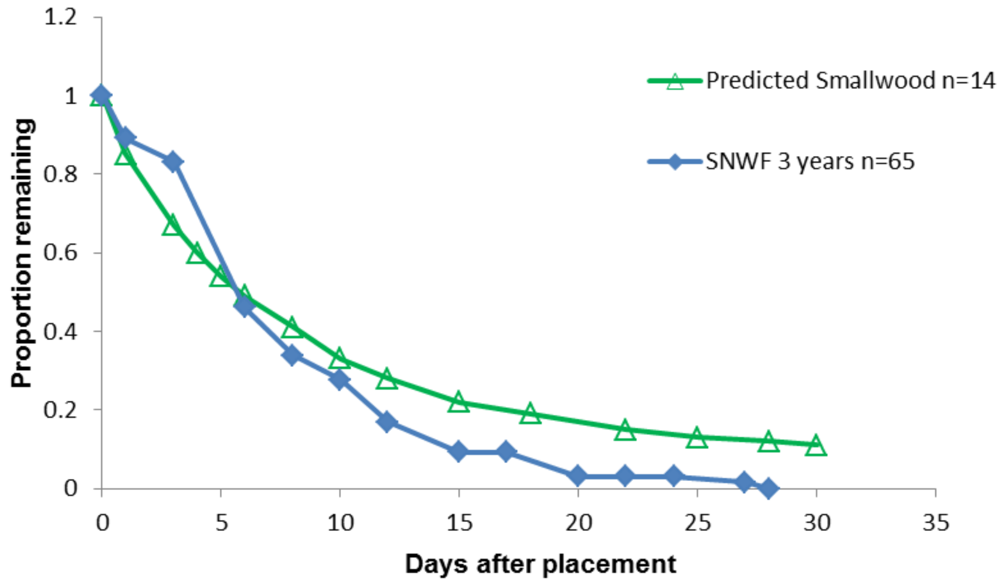


Figure 16. The combined results of three years of SNWF trials on hen carcass persistence involving 65 carcasses (not weighted by year – even though 2009 involved fewer carcasses that disappeared more quickly) compared with the modelled persistence of 14 chickens and game birds published by Smallwood (2007) from studies in the USA.

The combined results for all three SNWF trials are more similar to those presented by Smallwood (2007) for a smaller sample in the USA than is apparent from a comparison with the 'decay' function derived by Smallwood (Fig. 16). The actual data Smallwood (2007) presented show greater similarity.

While perhaps not too much should be read into this similarity given the small sample of Smallwood (2007) compared with those from SNWF, and a host of other potential coincidences, it is consistent with a tenet of Smallwood's (2007) paper. This is that carcasses of birds such as chickens (hens) and game birds disappear more quickly than other groups of birds. This was also shown by Urquhart et al. (in press) when directly comparing persistence of game bird carcasses with large raptor (*Buteo buteo*) carcasses. Palatability or attractive scents for scavengers may be the reason for this finding.

The implication of this for the SNWF studies is that most carcasses of collision victims and 'naturally' occurring carcasses probably persisted (and so were available to be found) for longer than the trial carcasses of hens. This would tend to counteract the likelihood that searcher efficiency was higher in the trial than under typical 'field' conditions when searching for collision victims (see above: *Searcher efficiency trial: comparison with previous SNWF trials*).

Implications for adjusted mortality rate and search interval

Smallwood (2007) presented an equation which can be used to adjust observed ('raw' turbine search) estimates of collision mortality rates to account for searcher efficiency, carcass removal and inter-interval search timings. The estimator of adjusted mortality rate, M_a, is as follows:

$M_a = c / (t \text{ x } p / I) (e^{I/t} – 1 / e^{I/t} – 1 + p)$ .... (equation 1)

where c is average number of carcasses observed per year (i.e. observed or raw mortality rate), t is the mean number of days for carcass removal, p is observer efficiency rate, and I is the search interval in days.

Smallwood (2007) also presented a second estimator, but as in 2009 and 2010, this gave very similar results to equation 1 for the 2014 results, and so equation 1 is used hereafter. For 2014, with a hypothetical observed mortality rate of 10 birds killed per year, under a 7 d search interval, equation 1 gave an adjusted mortality (M_a) of 16.0, which inferred that more than half of collision victims would be found under a 7 d search interval. With a hypothetical observed mortality rate of 10 birds killed per year, under a 7 d search interval, taking only hens, then across the three years the mean adjusted mortality (M_a) was 19.1, and with pigeons (2009) it was 19.3.

This result inferred that slightly more collision casualties would be found in 2014 than in the years of the previous two trials in 2009 and 2010 (Table 16). This is largely because of the increased carcass persistence rate (t, mean number of days for carcass removal) in 2014. Bringing this 2014 rate to the rate found in 2010, for example, gives an adjusted mortality (M_a) of 20.1 under a 7 d search interval (i.e. twice the hypothetical 'observed' unadjusted mortality of 10).

Table 16. Calculated values of adjusted mortality rates using the results of the SNWF searcher efficiency and carcass removal trials in 2009, 2010 and 2014 applied to equation 1, given a hypothetical unadjusted mortality of 10 collision victims and a 7 d search interval. The mean number of days for carcass removal (t) and observer efficiency rate (p) from the trials are also shown.

Carcass and year	t	p	Unadjusted mortality Mu	Adjusted mortality Ma
Hen 2009	5.3	0.73	10	22.9
Pigeon 2009	4.45	1.0	10	19.8
Hen 2010	6.0	0.895	10	18.3
Hen 2014	9.66	0.787	10	16.0

The purpose of the original 2009 trials was, in part, to inform and justify the selection of the time interval between searches of turbines for collision victims during autumn migration at SNWF. The 2009 trials indicated that an inter-search interval of seven days was a reasonable cost-effective balance between effort, cost and discovery of any substantial levels of collision mortality, and that (potential biases that could affect the trial results, both upward and downwards, aside) remains of about half of collision victims for the main target species should be found. The results from 2010 and, especially 2014, confirm these original trial indications and give some confidence that across the several years of the study there has not been major changes in the efficiency of searchers and that carcass persistence does not vary sufficiently to dispute the assumption that around half of all collision victims of target species should be found by the search protocol.

Searches for collision victims

The numbers of turbines searched during every autumn of operational period of the wind farm are presented in Table 17. The increase of total searches in autumn 2014 was due to the increased monitoring period, until the end of October.

Table 17. Number of carcass searches per autumn and turbine in the operational period of SNWF.

Turbine number	**Autumn 2010**	**Autumn 2011**	**Autumn 2012**	**Autumn 2013**	**Autumn 2014**	**Total searches**
8	6	8	8	10	13	45
9	6	8	7	10	12	43
10	6	7	10	10	14	47
11	6	7	9	11	17	50
12	6	10	9	11	19	55
13	6	9	9	9	17	50
14	6	9	7	10	15	47
15	6	9	7	10	15	47
16	6	6	9	10	15	47
17	6	6	9	12	13	46
18	6	4	8	12	14	44
19	6	8	9	12	15	50
20	6	9	10	12	14	51
21	1	6	8	10	16	41
22	6	6	8	13	14	47

Turbine number	Autumn 2010	Autumn 2011	Autumn 2012	Autumn 2013	Autumn 2014	Total searches
23	6	6	8	10	18	48
24	6	7	7	10	16	46
25	6	2	8	9	16	41
26	6	8	8	13	13	35
27	6	2	8	11	14	41
28	6	2	5	12	13	38
29	6	8	7	10	16	47
31	1	9	7	11	15	43
32	6	9	8	11	15	49
33	6	8	7	9	18	48
34	6	8	7	10	15	46
35	7	8	7	10	15	47
36	6	9	7	10	13	45
37	6	9	9	13	15	52
38	6	9	6	10	14	45
39	6	8	7	10	16	47
40	6	7	8	9	16	46
41	6	7	6	11	18	48
42	7	7	7	10	15	46
43	11	9	7	10	15	52
44	11	7	7	10	15	50
45	6	8	8	10	13	45
46	6	9	8	10	14	47
47	6	9	7	10	15	47
48	6	9	7	10	14	46
49	6	10	7	13	14	50
50	6	10	7	11	15	49
51	6	9	7	9	14	45
52	6	9	5	9	15	44
53	6	9	6	10	13	44
54	6	8	7	8	15	44

Turbine number	Autumn 2010	Autumn 2011	Autumn 2012	Autumn 2013	Autumn 2014	Total searches
55	6	9	7	10	18	50
56	6	8	7	9	14	44
57	6	9	7	8	14	44
58	6	9	7	9	14	45
59	7	9	7	9	16	48
60	6	9	7	11	15	48
Total	**315**	**404**	**389**	**537**	**777**	**2422**

Under this search regime during the autumn migration period, 11 bodies have been found that can be attributed to collision with turbine blades in 2014. The number of birds found dead under turbines in 2014 and species' conservation status according to IUCN are presented in Table 14.

Table 14. Collision victims recorded in autumn 2014.

English name	Latin name	N	Red Data book	IUCN
Yellow-legged gull	*L. michahellis*	5	Not listed	Least Concern
Eurasian Skylark	*A. arvensis*	3	Not listed	Least Concern
Black swift	*A. apus*	1	Not listed	Least Concern
Red-footed Falcon	*F. vesperinus*	1	Near Threatened	Near Threatened
Corn crake	*C. crex*	1	Vulnerable	Least Concern

The old remains of a White Pelican were found in a shelterbelt (from its state perhaps two years old). There were no signs of an impact trauma on the skeleton. Upon notification by a site visitor, a wounded White Stork was captured by the side of a road and was brought for treatment to the Green Balkans Bird Center in Stara Zagora. This rehabilitation center was swamped by scores of grounded injured storks that had been hit by vehicles elsewhere around the same time and brought for treatment. Therefore, both the pelican and the stork were apparently not associated with being a victim of collision with turbine blades.

The total number of collision victims across the five years of searching under operational turbines (22), broken down by species, is presented in Table 15.

Table 15. The number of carcasses found in periods of autumn migration during five years of operation of SNWF. For details see Methods and reports on the autumn migration period in previous years.

Species	**Carcasses attributable to collision**	**Conservation status according to IUCN** (IUCN 3.1)
Alauda arvensis	3	Least Concern
Apus apus	2	Least Concern
Acrocephalus palustris	1	Least Concern
Crex crex	1	Least Concern
Delichon urbicum	2	Least Concern
Gyps fulvus	1	Least Concern
Falco vespertinus	1	Near Threatened
Hirundo rustica	2	Least Concern
Lanius collurio	1	Least Concern
Larus ridibundus	1	Least Concern
Larus michahellis	5	Least Concern
Oreolus oreolus	1	Least Concern
Sylvia atricapilla	1	Least Concern
Total	**22**	

IUCN criteria were used for evaluation of bird conservation status because of the unknown origin of migratory populations in autumn when the movements of birds found dead can cover different continents. National criteria for the same species would be applicable for breeding populations of the same species in the breeding period in spring. The mortality rate at SNWF for five autumn seasons of carcass searches under every turbine every week resulted in an average of 0,08 birds per turbine per migratory season in total and cannot be remotely considered influential for the populations of any species.

Collision mortality: predictions before operation and empirical observations after operation

Before construction the substantive predicted potentially adverse effect of SNWF on autumn migrants was through increased mortality of birds through collision with turbine blades. As SNWF has been operational for five autumns it is appropriate to contrast the predictions of collision mortality made before construction with empirical observations made after operation.

Counts of key species

It is instructive first to compare the counts of birds made before construction (RSK Environment Ltd 2008, AES autumn report for 2008) with those made after operation (this report for 2014 and previous reports for autumn 2010 – 2013: see AES website). This gives total count data from nine autumns, with four from before construction (2004 – 2006, conducted by Bulgarian Academy of Science [BAS], plus 2008 conducted as part of AES studies at SNWF) and five post operation (AES autumn reports 2010 – 2014) (Table 16). The BAS data represent total counts over the migratory season and were restricted to the (potential, at the time) SNWF area. It is unclear if the BAS data are directly comparable with the later AES data inasmuch as effort and observation point locations.

'Peak counts' reported by BSPB before SNWF construction are also shown because these data were instrumental in deriving predicted collision mortality rates before construction (RSK Environment Ltd 2008) (Table 16). Details of the provenance of these peak counts are sketchy, only that they involved the proposed SNWF area and "the vicinity". They were presumably made at a time before or contemporary with those made by BAS. Being peak counts, all else being equal we should expect that if the BSPB 'total' counts were available (to be more comparable to the totals that can be extracted for both BAS and AES data) then such BSPB total counts should be even higher than the 'peak counts'. What is surprising, therefore, is that the BSPB peak counts are consistently and substantially higher (often by an order of magnitude) than the total counts gathered by BAS. Moreover, relatively few of the total counts 2008 – 2014 commissioned by AES are even similar (Table 16).

Table 16. Counts of species following the list considered as 'key species' in vulnerability to collision risk before SNWF was constructed (as reported by RSK Environment Ltd (2008), BSPB and BAS; and 2008 AES data) and after SNWF was operational (2010 – 2014 AES data: see this and previous AES autumn reports; highlighted in grey). BSPB data are 'peak counts' gathered in SNWF and "the vicinity", BAS and AES data are total counts across the main migration period gathered in SNWF.

	BSPB	BAS			AES					
Species		2004	2005	2006	2008	2010	2011	2012	2013	2014
White stork	196771	555	2999	22196	2998	24980	620	2525	11230	4639
White pelican	3081	148	79	335	120	252	277	1700	3285	1679
Honey buzzard	2209	2	451	395	58	1549	152	115	4284	113
Lesser spotted eagle	343	1	146	19	44	80	76	31	1966	509
Pallid harrier	260	1	18	4	8	18	4	7	7	15
Imperial eagle	6	0	0	0	2	0	0	0	0	0
Saker falcon	10	0	0	0	0	0	2	1	0	1

This strongly indicates that the BSPB 'peak counts' substantially exaggerate the total number of autumn migrants that typically pass through or over SNWF annually. It follows that use of these counts in a collision risk model will exaggerate the predicted number of collision victims at SNWF. The next section considers this in greater detail.

Predicted and observed collision mortality

Predictions of collision mortality using the model of Band et al. (2007) before SNWF was constructed were reported by RSK Environment Ltd (2008). These assumed a 95 % avoidance rate under the Band et al. Collision Risk Model, and the results depended on whether the count data provided by BSPB or collected by BAS were used (Table 17).

Table 17. Predictions of collision mortality made pre-construction under the Band et al (2007) model and assuming a 95 % avoidance rate for several 'key' species reported by RSK Environment Ltd (2008: Table 4.7) together with observed collision mortality derived from searches under operational turbines at SNWF.

Species	Predicted annual collisions		Predicted total collisions 2010 - 2014		Observed collisions 2010 - 2014
	BAS data	BSPB data	BAS data	BSPB data	AES SNWF data
White stork	14.6	86.1	73	430.5	0
White pelican	0.26	1.58	1.3	7.9	0
Honey buzzard	0.27	0.9	1.35	4.5	0
Lesser spotted eagle	0.09	0.15	0.45	0.75	0
Pallid harrier	0.01	0.13	0.05	0.65	0
Imperial eagle	0	0.0029	0	0.0145	0
Saker falcon	0	0.0046	0	0.023	0

Under any of the pre-construction scenarios modelled by RSK Environment Ltd (2008) the probability of an individual of a raptor species being killed in 2010 – 2014 at SNWF was not high, except for honey buzzard, when based on BSPB data four or five were predicted to be killed 2010 – 2014 (Table 17: no casualties have been found in five years). The contrast between predictions and observations is greatest for white stork when, using BSPB data, RSK Environment Ltd (2008) predicted that about 430 storks should have been killed by SNWF in 2010 – 2014 when none have been found to have been killed (even accepting, also, that the searcher efficiency and carcass persistence experiments have repeatedly shown – see earlier in this report – that about 50 % of all casualties will have been found by the regime searching for collision casualties).

RSK Environment Ltd (2008) considered that a TSS applied as mitigation could reduce the ‘worst case’ (i.e. predicted from BSPB data) collision mortality rates by an order of magnitude. Such that, for example, after deployment of the presumed effect of a TSS their collision prediction for white stork was reduced to 8.6 strikes per year (or 43 strikes over 2010 – 2014): see RSK Environment Ltd (2008: Table 4.9). Such predictions, even after implementation of a TSS, have not been observed at SNWF in 2010 – 2014 – no evidence of white storks colliding with turbine blades has been recorded, for example (Table 17).

The operation of SNWF, from five years of rigorous monitoring in autumns 2010 - 2014, has apparently not resulted in the levels of collision mortality as predicted before its construction. Why? The substantial discrepancy cannot be due to the implemented regime searching for collision victims under the turbines of SNWF, according to dedicated calibration experiments conducted at SNWF in 2009, 2010 and 2014. Three factors, in order of influence (highest first) probably explain why the pre-construction predictions have not been realized in the five years of collision mortality monitoring at SNWF:

1. The use of exaggerated BSPB estimates of the number of migrants which use SNWF as a ‘worst case’ scenario; typical total counts do not approach these estimates;
2. The use of a 95 % avoidance rate in the Band et al CRM; the level of avoidance is likely much higher; and
3. The deployment of the TSS.

CONCLUSIONS

Additional data collected in the autumn 2014 by standard methods with consistent and comparable to previous years' efforts confirmed the previous results and allowed evaluation of the long term effect of SNWF on bird migration. The long term monitoring in the same area has allowed the following conclusions:

1. The numbers of species passing through the SNWF territory in autumn varied by year with no trend for a decrease after SNWF was constructed and started its operation (Table 1).
2. The absolute number of observed birds naturally varied by year but with no trend for a decrease after SNWF was constructed and started its operation (Table 2).
3. The altitude of flight varied by years but with no overall trend for an increase after SNWF was constructed and started its operation (Table 4 and Figure 5).
4. There is no evidence for change in migratory direction (avoidance) associated with the wind farm territory. At a gross scale, birds did not demonstrate macro-avoidance of the turbines that could be considered as a change of migratory direction and, thereby, a change of migratory route (Tables 7, 8 9, and Figures 6, 7, 8 and 9).
5. The occurrence of autumn migrants in all seven autumn seasons was strongly correlated with typically short periods of a few days when strong westerly winds occurred.
6. Trials to estimate searcher efficiency and carcass persistence rates were conducted in 2014 to calibrate the results of searches for collision victims and to compare with similar trials conducted in 2009 and 2010. The results indicated similar searcher efficiency rates to previous trials but longer carcass persistence rates. The 2014 results were consistent with previous trials however, in the context of their main applied uses, such that the established protocol of seven day intervals between searches of turbines for collision victims should find about half of any casualties of collision for the target species.
7. During five years of wind farm operation, carcass searches during the autumn periods revealed a total of 22 collision victims. Predictions of collision

mortality made before SNWF was constructed included that up to nine white storks would be killed by collision with turbine blades every autumn after mitigation (TSS) had been implemented, with over 86 predicted to be killed each autumn before TSS mitigation, based on BSPB data (i.e. up to 43 white storks were predicted to be killed 2010 – 2014 with a TSS in operation, whereas no white stork has been found killed in this period from observations). This prediction was based on an exaggerated 'peak count' of white storks supplied by BSPB (no total counts in any of nine autumn seasons have come even close to the number of white stork migrants claimed by BSPB at SNWF). This exaggerated BSPB estimate of the number of birds at risk of collision together with the use of a 95 % avoidance rate (a higher avoidance rate is more likely) is probably the main reason why observed collision mortality has been substantially below pre-construction predictions.

8. Records of collision mortality do not indicate any possibility of an adverse impact of SNWF on any bird population passing through the wind farm territory.
9. The application of the Turbine Shutdown System (TSS) may have had a significant contribution to the low level of direct mortality registered in the operational period of SNWF. Even in the absence of TSS, however, it is unlikely that the pre-construction predictions of mortality would have been observed, in part because these predictions were based on inflated estimates of the numbers of migrants that occur at SNWF.
10. The substantial data collected in seven autumn seasons indicate that the operation of SNWF does not constitute a major obstacle or threat, either physically or demographically, to populations of migrants passing through its environs.

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